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An Investigation of the Nature of Vocal Fold Diadochokinesis of Adult Subjects and of the Effect of Pitch, Intensity, and Aging Upon the Performance of This Phonatory Task.

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AN ABSTRACT

This study was concerned with the nature of vocal fold diadochokinesis and the effects of pitch, intensity, and aging upon rate, periodicity, and pattern of the phonatory task. Rapid repetitions of the syllable [hʌ], which require reciprocating abduction-adduction movements of the vocal folds, were used to test vocal fold diadochokinesis. Nature referred to certain physiological processes necessary for coordinated performances of the task. Rate was the mean number of syllables uttered per second. Periodicity described regularity of occurrence of syllable repetitions expressed in terms of variability among rates of nine, one second samples. Pattern denoted (1) the percentage of abducted syllables and (2) the percentage of phonation time during productions of the syllable [hʌ].

Samples of vocal fold diadochokinesis performed by (1) forty young adult females with and without auditory masking, (2) ten individuals before and after undergoing topical anesthetization of the larynx, (3) forty young adult women varying pitch and intensity of their phonations, and (4) three groups of forty women, classified according to age, were tape recorded. Graphic level tracings and sound spectrograms were made of the recorded samples, and

rate, periodicity, pattern, pitch, and intensity measurements were obtained from these representations. The significance of the data referable to experimental treatments was determined by computer programmed analyses of variance, by t-tests, and by a Wilcoxon matched-pairs signed-ranks test.

The results indicated that disruption of auditory feedback utilizing a white noise masking signal produced a significant dimunition in the rate of vocal fold diadochokinesis. It was inferred that coordinated abduction-adduction movements of the vocal folds are either synchronized using information relayed from the auditory feedback mechanism, or that a person's approach to the phonatory task is altered when auditory masking is presented. The periodicity and pattern of vocal fold diadochokinesis were not affected significantly by disruption of auditory feedback.

Although disruption of laryngeal somesthetic feedback produced no significant changes in vocal fold diadochokinetic rate, periodicity, or pattern measurements, the reader is advised to accept this finding with caution. The number of subjects participating in laryngeal anesthetization procedures was small, and the adequacy of the anesthesia in disrupting somesthetic feedback is subject to question. Even though not statistically significant,

increases in vocal intensity during all but one subject's diadochokinetic performance were noted after laryngeal somesthetic feedback was disrupted. This information is pertinent for future studies concerned with relationships between vocal parameters and disruption of laryngeal somesthetic feedback.

Rates of vocal fold diadochokinesis were found to be significantly altered due to variations in pitch and intensity. Moreover, the results revealed that pitch and pitch x intensity interaction were significant main effects. Subjects produced highest rates at comfortable pitch and intensity levels. This finding suggests that this manner of production would be appropriate for use in clinical evaluations of vocal fold diadochokinetic ability. In view of the results, deviant rates might occur when the task is performed by patients having functional pitch and vocal intensity problems.

The percentages of abducted syllables were observed to be significantly affected by variations in pitch and intensity. Although interaction between treatments was not evident, pitch and intensity were significant main treatment effects. Extremes in intensity at high and low pitches produced significant decreases in the percentages. This finding demonstrates that pitch and intensity place restrictions on vocal fold abduction. Periodicity and

percentages of phonation time were not found to change significantly due to variations in pitch and intensity.

The present research has demonstrated that rate, periodicity, and pattern of vocal fold diadochokinesis were not significantly different due to aging. Therefore, deviant performances of the task by aging women may indicate the need for medical referral.

CHAPTER I

INTRODUCTION AND PURPOSE OF THE STUDY

In the past the speech pathologists' clinical evaluation of patients with phonatory problems consisted primarily of subjective analyses of the individuals' phonatory skills. Recently, experimenters (41, 42) have studied (1) maximum ability to sustain phonation, (2) maximum pitch range, and (3) maximum vocal intensity. These tasks have potential usefulness for the objective evaluation of phonatory skills.

Another task which has been suggested for use as a diagnostic tool in the clinical evaluation of phonatory problems is the maximum ability to rapidly abduct and adduct the vocal folds while repeatedly uttering a syllable containing a glottal fricative and a vowel. This activity has been referred to as vocal fold diadochokinesis (6, 44).

Although vocal fold diadochokinesis has been used in measuring phonatory abilities of clinical subjects (6, 44), there has been no attempt to evaluate the nature of the task and the variables which may affect its production. It is not known whether tests of diadochokinesis requiring phonation are measuring coordination of motor processes only, or if they are dependent upon the person's efficiency in utilizing auditory and somesthetic feedback to synchronize

the motor movements. Furthermore, the effects of aging and the importance of vocal pitch and intensity characteristics on rapid syllable repetition requiring vocal fold abduction and adduction have not been assessed. Information relative to these variables would better enable the speech pathologist to utilize vocal fold diadochokinetic measurements in diagnostic workups.

The purpose of this research is, first, to obtain information about the nature of maximum vocal fold diadochokinesis utilizing the syllable [hʌ], and, secondly, to determine the effects of pitch and intensity of phonation and of aging upon the rate, the periodicity, and the pattern of this phonatory task.

Definition of Terms. For the purpose of this study the following terms have these special connotations:

By nature of vocal fold diadochokinesis is meant the physiological process involved in coordinating rapid, repetitive abductions and adductions of the vocal folds while producing the syllable [hʌ] repeatedly.

Rate refers to the mean number of syllables uttered per second.

Periodicity describes the regularity of occurrence of syllable repetitions expressed in terms of the variability among the rates of nine, one second periods.

Pattern refers to: (1) the percentage of syllables

in which, according to spectrographic analyses, phonation ceases during production of the [h] sound, and (2) the percentage of phonation time, the duration of phonation in proportion to the time required to utter the complete syllable.

Organization of the Dissertation. The remainder of the paper will be organized as follows: Chapter Two will present a review of the literature related to the problem and a statement of the research hypotheses. Subjects and procedures will be described in Chapter Three. In Chapters Four and Five the results and a discussion of these findings will be reported. The investigation will be summarized and conclusions will be stated in Chapter Six.

CHAPTER II

REVIEW OF THE LITERATURE AND STATEMENT OF THE EXPERIMENTAL HYPOTHESES

In the previous chapter it was pointed out that although vocal fold diadochokinesis has been recommended as a useful test of phonatory abilities, little information is available with regard to the nature of the task and the effects of certain factors upon its production. It may even be possible to question whether a diadochokinetic process exists during abduction and adduction of the vocal folds. To enable the reader to better understand vocal fold diadochokinesis, literature pertinent to the topic will be reviewed in this chapter. This material will be followed by a statement of the research hypotheses formulated for the study.

A. VOCAL FOLD DIADOCHOKINESIS

Diadochokinesis is defined in Dorland's Medical Dictionary (9) as the function of arresting one motor impulse and substituting one that is diametrically opposite. Information reported by Faaborg-Anderson, Dana, and Brewer (4) and by Buchtal (5) concerning electrical impulses of the intrinsic laryngeal musculature suggests

that a diadochokinetic process occurs during abduction and adduction of the vocal folds. Utilizing an electromyographic technique, these authors found that an increase in electrical activity in the adductor muscles occurred nearly simultaneously with the initiation of phonation and that this increase was accompanied by a reduction in electrical activity of the abductors. Additionally, shortly before the cessation of phonation an increase in electrical activity in the abductors occurred, and with cessation of phonation the electrical activity in the adductors decreased.

B. PHYSIOLOGY OF VOCAL FOLD ABDUCTION AND ADDUCTION

Movement of the arytenoid cartilages during abduction and adduction of the vocal folds has been studied by several investigators (16, 24, 25, 51, 54). Roentgenograms and experiments with cadavers have been utilized in these studies.

Moore and von Leden (54) have given a complete description of the arytenoid cartilages. Their research has indicated that the cartilages are joint structures resembling elongated, shallow, ball and sockets which are situated on the lateral aspects of the cricoid rim. The right angle placement of the longitudinal dimension of the two facets permits a rocking or rotating movement around the axis of the joint during abduction and adduction of the

vocal folds.

During phonation the vocal process of the arytenoid cartilage, to which the vocal fold is attached, rotates from a posterolaterocephalad position in an anteromediocaudal direction (53). Moore and von Leden stated that this rocking or rotating movement:

> . . . lowers the vocal processes in adduction and slightly shortens the vocal cords: conversely, abduction results in an elevation of the vocal cords (54, 59).

Although von Leden (53) has suggested that internal joint rotation is the principle arytenoid movement, other experimenters (25, 36, 39, 40) have used the terms lateral, medial, forward, and backward to describe arytenoid adjustments during phonation. The vocal processes of the arytenoids were said also to undergo torsion during vocalization (24).

Movement of the laryngeal musculature involved in abduction and adduction of the vocal folds has been studied, also. There is considerable agreement noted among speech scientists with regard to classification of this musculature. Experimentation has revealed that the lateral cricoarytenoid muscle is the principle adductor of the vocal folds (4, 11, 23, 40, 47). This paired muscle pulls on the muscular processes of the arytenoid cartilages, to which it is attached, to accomplish approximation of the

folds. Electromyographic studies revealed that significant increases in the electrical activity of the cricothyroid, thyro-arytenoid, vocal, and transverse and oblique arytenoid muscles occurred during adduction of the vocal folds. A noticeable increase in their electrical activity was recorded just before phonation was initiated (12).

Electromyographic evidence provided by Faaborg-Anderson and Buchtal (12) has shown that electrical activity of the posterior crico-arytenoid was greatly inhibited during phonation. Authors (4, 5, 23, 26, 35, 37, 40) have generally classified this musculature as an abductor of the vocal folds. Contraction of this paired muscle, which has its insertion on the muscular process of the arytenoid cartilages, widens the glottic space.

C. TESTS OF VOCAL FOLD DIADOCHOKINESIS

Several investigators have attempted to measure vocal fold diadochokinetic abilities utilizing vowel and syllable repetitions (6, 41, 44). In 1961, Canter (6) used the rapid repetition of the syllable /ha/ as a vocal fold diadochokinetic task in the examination of the phonatory abilities of Parkinsonian patients and normal subjects. The author advocated repetition of a syllable rather than an isolated vowel. His rationale was that it may be possible to repeatedly phonate an isolated vowel by

producing "pulses of air pressure acting on a fixed laryngeal valve." (6, 60) Repetitive production of a syllable containing a vowel and a glottal fricative, the author added, would be more apt to call for a continuous air stream modulated by laryngeal adjustments. i.e., abductions between phonations. Canter (6) measured the subjects' rate of vocal fold diadochokinesis by counting the intensity peaks present on power level tracings of tape recorded samples of the phonatory task.

In 1963, Sanders (44) also reported utilizing rapid repetition of the syllable /ha/ in the study of phonatory abilities of patients with pseudohypertropic muscular dystrophy. This investigator also analyzed power level tracings of the subjects' performance of the task to determine the rates of vocal fold diadochokinesis.

In 1963, as part of a study of the phonatory abilities of normal persons, Ptacek and Maloney (41) included several diadochokinetic tasks. They studied the performance of two young adult groups and two geriatric groups during rapid repetition of the following sounds and syllables: [pʌ], [tʌ], [kʌ], and [ʌ]. Graphic level tracings were made as each individual produced the sounds as rapidly as possible. Diadochokinetic rates were established by analyzing the graphic level tracings. In an unpublished paper describing the study, the investigators indicated that they assumed

that they were testing maximum vocal fold diadochokinesis when the subjects repeated the vowel [ʌ] rapidly. They stated that the "vocal folds themselves act as articulators in initiating and terminating the sound." (41, 6)

D. NATURE OF VOCAL FOLD DIADOCHOKINESIS

The importance of sensory feedback to speech production has been discussed by several authors (8, 14, 38, 56). It has been theorized that feedback mechanisms provide the regulation and control which are necessary for synchronized vocalizations. Fairbanks (14) postulated that although the unit of speech control is yet unspecified, the ear appears to be the primary feedback control unit with somesthetic feedback providing secondary data to aid in the operation of the vocal mechanism. Davis (8) also advanced the above theory and used the difficulties the deaf have in learning to speak with normal prosodic characteristics to defend his postulates.

As a result of these early servosystem theories, speech scientists have begun to study disruption of various aspects of sensory feedback in relation to speech variables. The effect of several different methods of altering auditory feedback channels has been investigated (2, 3, 7, 50, 52, 57, 58, 59). One approach has been to eliminate auditory feedback as much as possible through

the use of masking (1, 2, 19, 20, 31, 34, 43, 52, 55, 58). Masking, according to Licklider (28), is the opposite of the analysis of sound. It represents the inability of the auditory mechanism to separate the tonal stimulation into components and to discriminate between the presence and absence of one of these components.

To learn more about the nature of speech production, investigators have utilized white noise to minimize auditory feedback and have reported significant changes in certain vocal parameters as a result of their experimentation (2, 19, 31, 34, 43, 55). Increases in intensity and raises in pitch were the most frequently mentioned vocal alterations (31, 43, 55). Ringle and Steer (43) noted an average peak intensity value of 72.7 db SPL for their subjects' phonations during the control condition and an increase of 10 db during the experimental treatment when masking was presented. Guttman (19) reported the same increment in the sound pressure level of his patients' voices when auditory masking was utilized.

The above observations were based upon measurements of conversational speech and oral reading samples. The author was unable to find research evidence concerned with changes in maximum phonatory abilities due to disruption of auditory feedback. However, it seems reasonable to theorize that similar vocal alterations would occur if

auditory feedback were disrupted when phonatory tasks such as vocal fold diadochokinesis are being performed.

Attempts have been made to study the nature of speech production when other sensory channels were disrupted. Guttman (19) classified these feedback channels as non-auditory and appeared to mean by this term the somesthetic feedback mechanisms.

Frisk (17) pointed out that Guttman (19) was the first speech scientist to utilize anesthetization of the oral structures to disrupt somesthetic feedback during speech activities. The findings of subsequent investigators seem to be in agreement with Guttman who observed that non-auditory cues seemed to be of great importance in aiding subjects to correctly articulate isolated words and connected speech during oral reading (32, 43, 55).

Speech scientists have also suggested that non-auditory or somesthetic feedback channels are important in laryngeal functioning. Meader and Muyskens (35) have theorized that somesthetic feedback from the muscles, tendons, and joints of the larynx is important for synchronizing phonation. Although the role of sensory feedback in rapid vocal fold abduction-adduction has not been studied, recently research has been undertaken to investigate the effect of disrupting laryngeal somesthetic feedback on vocal fold vibration. Zemlin (60) utilized high

speed cinematography before and after topical anesthetization of the larynx was administered to obtain measurements of vocal fold vibration while subjects phonated a vowel sound. No significant alterations in the vibratory pattern of the folds were found.

Researchers who have studied various types of maximum phonatory abilities have not made an attempt to probe the underlying sensory feedback mechanisms which might be responsible for guiding individuals through correct patterns of performance during these tasks (41, 42). It seems reasonable to hypothesize that the performance of maximum phonatory tasks, which require speed of movement, might be affected by disruption of somesthetic feedback.

E. FACTORS IMPORTANT IN MEASURING VOCAL FOLD DIADOCHOKINESIS

Although speech pathologists have been interested primarily in rate of vocal fold diadochokinetic movement, Canter's (6) research findings indicated that there appear to be other factors which are important in the understanding of the nature of diadochokinetic abilities. These include the periodicity and pattern of phonation during the performance of such tasks. Periodicity was not discussed by Canter, but apparent disturbances in this phenomenon were evident from visual inspection of photographs, included in

the author's dissertation, of graphic level tracings of a Parkinsonian patient's rapid repetition of a syllable. The investigator (6) described a distinct pattern of phonation which occurred during the production of diadochokinetic tasks. This pattern was characterized by a decided lengthening of the vowel sound which was shown as a flattened graphic level tracing without discrete intensity peaks. Canter designated this phenomenon as "freezing." (6, 117)

During freezing, according to Canter (6), the subject appeared either to be unable to prevent the articulators from assuming a fixed position, or to be unable to complete required articulated movements. Although this pattern was most observable in the Parkinsonian patients' tracings, it also occurred sporadically in tracings of the control persons' phonations: complete or partial freezing was seen in fourteen of the seventeen Parkinsonian tracings, and partial freezing was seen in the graphs of eight of the seventeen control subjects. The investigator (6) remarked that apparently rapid abduction-adduction movements of the vocal folds and other articulators are not only difficult for neurologically involved patients, but for many persons with normal neurological control also.

F. VARIABLES AFFECTING VOCAL FOLD DIADOCHOKINESIS

Although the literature previously reported has described measurements of rate of vocal fold diadochokinesis (6, 41, 44), no mention has been found of the fundamental frequency and intensity with which the task was performed. The results of the work of Ptacek and Sander (42) indicated that these variables were important to consider when evaluating phonatory skills. The authors reported that measurements of maximum vowel duration appeared to be a function of both the frequency and intensity of the subjects' phonations.

A recent investigation conducted by Ptacek and Maloney (41) has indicated that aging is also an important variable to consider when evaluating phonatory skills. The authors noted significant differences between young adults and geriatric subjects in terms of maximum pitch range, maximum vowel intensity, and diadochokinetic abilities.

If the speech pathologist is to utilize vocal fold diadochokinesis in the evaluation of phonatory abilities, he must be aware of the effect of the previously mentioned variables on the task. Unless such information is made available, measurements of vocal fold diadochokinesis will be of little value and interpretations of these assessments may lead to erroneous conclusions concerning phonatory abilities.

G. EXPERIMENTAL HYPOTHESES

This study was designed to test the following hypotheses:

1. There are no significant differences in the rate of vocal fold diadochokinesis (1) when the task is performed at a comfortable pitch and intensity level, and (2) when it is performed at a comfortable pitch level, with intensity controlled and binaural masking disrupting auditory feedback.

2. There are no significant differences in the periodicity of vocal fold diadochokinesis (1) when the task is performed at a comfortable pitch and intensity level, and (2) when it is performed at a comfortable pitch level, with intensity controlled and binaural masking disrupting auditory feedback.

3. There are no significant differences in the pattern of vocal fold diadochokinesis (1) when the task is performed at a comfortable pitch and intensity level, and (2) when it is performed at a comfortable pitch level, with intensity controlled and binaural masking disrupting auditory feedback.

4. There are no significant differences in the rate of vocal fold diadochokinesis before and after topical anesthetization of the larynx.

5. There are no significant differences in the periodicity of vocal fold diadochokinesis before and after topical anesthetization of the larynx.

6. There are no significant differences in the pattern of vocal fold diadochokinesis before and after topical anesthetization of the larynx.

7. There are no significant differences in the rate of vocal fold diadochokinesis when pitch and intensity levels are varied.

8. There are no significant differences in the periodicity of vocal fold diadochokinesis when pitch and intensity levels are varied.

9. There are no significant differences in the pattern of vocal fold diadochokinesis when pitch and intensity levels are varied.

10. There are no significant differences in the rate of vocal fold diadochokinesis when the task is performed by young adult women, by mature women, and by women in the late senescent period of life.

11. There are no significant differences in the periodicity of vocal fold diadochokinesis when the task is performed by young adult women, by mature women, and by women in the late senescent period of life.

12. There are no significant differences in the pattern of vocal fold diadochokinesis when the task is

performed by young adult women, by mature women, and by women in the late senescent period of life.

CHAPTER III

SUBJECTS AND PROCEDURES

Electromyographic evidence cited in the preceding chapter suggests that movements of the vocal folds during initiation and termination of phonation can be classified as a diadochokinetic process. It was pointed out that a syllable containing a glottal fricative and a vowel appears to be the best test of vocal fold diadochokinesis.

Observations of previous investigators showed that while it is important to measure rate, a better understanding of the phonatory task would be obtained if periodicity and pattern assessments were made, also. A review of the effect of disruption of feedback channels and of variations in pitch, intensity, and aging on conversational speech and phonatory activities revealed that performances of vocal fold diadochokinesis might also be altered by these modifications.

Hypotheses relative to the above factors were formulated by the investigator. Consideration of these hypotheses led to the design of the present research. In this chapter a description will be presented of the selection of subjects who participated in the study, and of the experimental procedures employed.

A. SUBJECTS

The present investigation was concerned with the effect of (1) disruption of auditory feedback, (2) disruption of somesthetic feedback, (3) variations in pitch and intensity, and (4) aging upon vocal fold diadochokinesis. Four groups of subjects were selected for the implementation of the study. Three of the groups were selected to ascertain the effects of aging on vocal fold diadochokinesis. Due to Jenkin's (21) findings that females are slightly superior to males in diadochokinetic rates, only female subjects were included in these three groups. The age ranges of the women were chosen to coincide with Stieglitz's (49) aging classifications: young adult, twenty to forty years of age; later maturity or early senescence, forty to sixty years of age; and late senescence, sixty to eighty years of age. Each of the groups included forty persons. The forty females in the young adult group were also used to study the effects of disruption of auditory feedback and of variations in pitch and intensity upon vocal fold diadochokinesis.

A fourth experimental group, composed of ten individuals, was selected to study the effect of disrupting somesthetic feedback upon vocal fold diadochokinesis. Since these persons were to serve as their own controls in the

experiment, sex and age were not considered in selecting subjects for this group.

1. General Considerations in Subject Selection

Certain criteria were established to aid in selecting the above groups of subjects. Canter's (6) research findings and clinical observations pointed to differences in vocal fold diadochokinesis when performed by persons with phonatory problems associated with neurological diseases. Therefore, it was believed to be imperative that none of the subjects participating in the present study have known neurological pathology. Because it was not possible to schedule neurological examinations for all of the subjects who were to participate in the study, the investigator included those persons who reported that they had never been diagnosed as having a neurological disease. This information was obtained when the one hundred and twenty female subjects were contacted initially by the examiner. Information concerning neurological status of the ten individuals participating in the fourth group was obtained from their Charity Hospital files before the testing periods were scheduled.

Individuals were also not considered acceptable for the study if they had a history of or presently were bothered with respiratory disease. The phonatory task was

to be performed at maximum speed for five seconds (See Procedures), and considerable breath was required to continuously repeat the syllable for this period of time. If breath control were deficient, due to respiratory manifestations, it seemed probable that the rate measurements would be subject to error. Information referable to the subjects' respiratory status was obtained in the same manner as described above for the neurological criteria.

The current health condition of the individual was also considered important in subject selection. When contacted initially, persons were asked to notify the examiner if they were ill on the day when they were to come to the Clinic. Appointments were rescheduled if the subject had a cold or any indication of febrile illness causing inflammation of the mucous membranes which might affect the performance of vocal fold diadochokinesis. Again the investigator relied on subjective evaluations of present health except for the ten persons in the fourth experimental group. These subjects received a medical examination by an otolaryngologist.

Since one of the purposes of this study was to gain information which could be utilized in the clinical evaluation of persons with phonatory problems, the criteria of "normal voice quality" seemed essential for all subjects participating in the experiment. When the person was

contacted regarding his willingness to be a participant, the investigator determined whether the quality of his voice was within normal limits.

To validate the investigator's judgments of voice quality, a tape recording was prepared containing the voices of ten individuals who were prospective participants for the study. Five normal and five deviant voices, judged by the investigator, were dubbed onto a tape with a fifteen second interval between each sample. To evaluate the investigator's ability to recognize normal and deviant voice quality, her assessments were compared with the judgments of five speech therapists with at least a Master's degree and with extensive experience with patients having voice disorders. Prior to listening to the tape the judges read the following directions:

> You have been asked to judge the voice quality of ten persons who were interviewed prior to being asked to participate in a research study concerning the phonatory abilities of normal women.
>
> Only persons with normal voice quality were acceptable for the investigation. Some of the women whose voices are on the recording were eliminated because of deviant voice quality.
>
> As you know, occasionally individuals may use a glottal attack for emphasis in conversation. Therefore, recordings in which persons have utilized this feature for inflectional purposes may be judged normal.
>
> Please listen to the complete tape once, then the tape may be played again. After the second playing, indicate whether the voice was NORMAL or DEVIANT by placing an N or a D on your evaluation sheet.
>
> Thank you for your help.

Differences in the investigator's and the judges' assessments of normal and deviant voices were compared using the chi-square test (18, 258). The result, a chi-square of 1.62, was not statistically significant. It can be inferred, therefore, that the investigator and the five speech therapists judged voice quality similarly.

Three weeks after the first assessments were made, the ten subjects' voices were randomized and re-dubbed on tape. To determine intra-judge reliability, the speech therapists again judged the recording. The chi-square test (18, 258) was calculated to test the differences between the first and second judgments of voice quality. A chi-square value of .02 resulted, which was highly insignificant. This statistic indicated that the judges consistently agreed with themselves.

Hearing acuity was also thought to be important in the selection of some of the subjects. As mentioned above, the performances of the young adult women were to be utilized in determining the effect of disrupting auditory feedback on vocal fold diadochokinesis. If a subject's hearing were deficient, she might have learned to compensate for losses in auditory feedback. Her reaction to further disruption would probably be less noticeable than the reaction of a person with normal hearing. In an attempt to obtain subjects with normal auditory feedback, a hearing

criterion of 20 db (re: normal hearing) in both ears for frequencies of 500, 1000, and 2000 cycles per second was established for this group.

Since the measurements of the comfortable pitch and intensity samples of the three groups of women were to be compared and the importance of auditory feedback on the phonatory task had not been ascertained, hearing acuity was considered an important matching variable. Subjects in the mature group were required to meet the hearing threshold criterion set for the young adult group. However, because hearing losses are reportedly frequent in individuals over sixty years of age, it was decided to raise the threshold slightly for the oldest age group (41). This would avoid eliminating women whose hearing acuity was normal for their age.

To establish a "normal" hearing threshold at 500, 1000, and 2000 cycles per second, to be utilized in selecting elderly subjects, hearing responses of sixty senescent women were obtained and averaged. The data yielded mean thresholds of twenty-two db in the better ear and twenty-eight db in the poorer ear.

Before subjects were asked to participate in the investigation they were given a hearing test at 500, 1000, and 2000 cycles per second. Only those persons whose thresholds were within the limits described above were

included in the experiment.

Hearing acuity was not considered an important variable in the selection of the subjects in the fourth experimental group. The rate, periodicity, and pattern measurements were to be made of each individual's performance of vocal fold diadochokinesis before and after the laryngeal anesthetization procedures. Therefore, each subject served as his own control in the investigation.

It was necessary to establish a special criterion for subjects in the young adult group because these persons were to participate in testing the effect of varying pitch and intensity on vocal fold diadochokinesis. The procedures required the subjects to alter their phonations from low, to comfortable, to high pitch using three intensity levels for each pitch condition. Therefore, it was essential for them to be able to control their phonations. When scheduling testing sessions, the examiner asked each prospective subject to imitate phonations of varied pitches and intensities. If the person were judged to be unable to accomplish this task, she was not included in the study.

2. Clinical Description of the Subjects

The subjects in the young adult group met the selection criteria of being in good health and having

normal hearing and voices. The women did not have a history of respiratory or neurological pathology, and they were able to control vocal pitch and intensity adequately to perform the required tasks. Their ages ranged from twenty to thirty-nine years; the mean age for the group was 26.9 years. The women were nurses, housewives, students, salesclerks, domestics, switchboard operators, speech therapists, nuns, secretaries, and laboratory technicians.

The women comprising the mature group also met the physical, vocal, and hearing criteria outlined above. Their ages ranged from forty to fifty-nine years, and the group mean age was 49.8 years. The subjects' vocations were similar to those of the young adult group.

The late senescent group was made up of women ranging from sixty to eighty years of age. The group mean age was 70.4 years. The health, vocal, and hearing status of these females corresponded to the criteria described previously. Most of the women were members of the New Orleans Golden Age Clubs and the Charity Hospital Guild. However, a few of the subjects were employed as secretaries, as bank clerks, and as switchboard operators.

The fourth experimental group included ten patients seen in the Otorhinolaryngology Clinic at Charity Hospital, New Orleans, Louisiana, for nose or ear pathology. This group was composed of eight male and two female subjects

who were in good health, who did not have a history of respiratory or neurological disease, who had normal voice quality, and who, according to laryngeal examination, had normal laryngeal structures and functioning. The subjects' ages ranged from sixteen to thirty-nine years; the mean age was 23.7 years. Four of the individuals were students, one was a domestic, four were unskilled laborers, and one was a salesman.

B. PROCEDURES

The twenty to thirty-nine year age group performed tasks designed to provide information concerning the disruption of auditory feedback and the effect of variations in pitch and intensity on vocal fold diadochokinesis. Additionally, this group's production of the phonatory task at a comfortable pitch and intensity level was compared with the performance of the subjects in the mature and late senescent groups to evaluate the effects of aging on vocal fold diadochokinesis.

Measurements of vocal fold diadochokinesis before and after the fourth experimental group underwent topical anesthetization of the larynx were used to determine the effects of somesthetic feedback disruption upon the performance of the phonatory task.

1. Recording Equipment and Calibration Procedures

The subjects' utterances during the performance of vocal fold diadochokinesis were recorded on an Ampex tape recorder (Model PR-10). To ascertain the accuracy of the recording equipment, certain calibration procedures with regard to the frequency and intensity characteristics of the tape recorder and the speaker (Ampex Speaker-Amplifier Assembly Model SH-10) were carried out before the testing sessions were scheduled. In addition to learning whether the recording equipment could handle sound signals without distortion, procedures were undertaken to enable the investigator to make intensity measurements of the subjects' utterances during the performance of vocal fold diadochokinesis. A taped sound pressure level reference tone was established for this purpose.

a. Frequency and intensity characteristics of the recording equipment. A beat frequency audio-generator (General Radio Type 1304-B), regulated for a constant output voltage of one volt across the appropriate frequency range, was utilized to determine the accuracy of the recording equipment. Pure tones in 100 cycle increments covering a range from 100 to 1000 cycles per second were produced by the generator and recorded on tape (Scotch $\frac{1}{2}$-120-12). To maintain a constant output voltage, the voltage output of the audio-generator was monitored with a vacumn tube volt

meter (General Radio, Type 1803-B). The recorded signals were played through the speaker and the frequency and intensity of the tones were measured utilizing an oscilloscope (Tektronic, Type 3A72). The frequency response of the equipment was essentially flat, and intensity measurements were within the manufacturer's specifications of ± 2 db.

b. Sound pressure level reference tone. In order to measure the intensity of the tape recorded samples of vocal fold diadochokinesis, a reference level in terms of sound pressure units had to be established. It was decided to record all of the samples with a constant zero volume setting on the tape recorder. The volume indicator was set so that a 1000 cycle per second tone at an intensity level of 80 db SPL played into the recorder would peak the meter at zero.

The 1000 cycle per second tone, produced with the audio-generator set at one volt, was played through the speaker-amplifier into the microphones of the sound level meter (General Radio, Type 1564-A) and the tape recorder which were stationed eight inches from the source of the sound. The sound level meter was set at 20 kc weighting, fast speed, with an 80 db setting on the attenuator dial. The volume of the speaker was adjusted until an 80 db SPL

reading was maintained on the meter. Then a zero reading on the tape recorder's VU meter was obtained by regulating the recorder's gain control.

Prior to each day of testing, this sound pressure reference tone was established. The tone was then recorded on the tapes for fifteen seconds and was utilized in measuring the sound pressure level of each person's samples of vocal fold diadochokinesis.

2. Testing Environment

The samples of vocal fold diadochokinesis were collected in three testing rooms with noise levels of approximately 54, 64, and 68 db SPL. During the testing period the subjects were seated in a comfortable, but stabilized position. To maintain a constant distance between the person's lips and the diaphragm of the microphones, two devices were utilized. The first was a head rest which held the subject's head in a stationary position. The second was a halter upon which the microphones of the tape recorder (Electro-Voice, Model 636) and of the sound level meter were mounted contiguously. This halter was hung around the subject's neck and was adjusted so that the microphones were eight inches from the person's lips.

3. Collection of Data

Rapid repetition of the syllable [hʌ] was used as the test of vocal fold diadochokinesis in this study. The investigator demonstrated each treatment condition cautioning the participants to produce the syllable distinctly. The subjects were told to perform the tasks more slowly if the syllables were not clearly articulated. Three practice trials were given every time a new experimental condition was introduced. This was done to minimize practice effect during the tape recording of the samples. Three trials of each condition to be described below were then tape recorded to provide samples of vocal fold diadochokinesis. The experimental conditions were presented randomly to eliminate measurement error from practice and fatigue.

a. Procedures utilized to study the nature of vocal fold diadochokinesis.

1. Ascertaining the importance of auditory feedback. Three experimental conditions were performed by subjects in the young adult group to determine the effect of disrupting auditory feedback upon vocal fold diadochokinesis.

(a.) Comfortable pitch-comfortable intensity. The subjects uttered the syllable [hʌ] as rapidly as possible for three five second trials using a comfortable pitch and

intensity level.

(b.) Comfortable pitch-controlled intensity with masking. During these three five second trials the subjects produced the task as rapidly as possible at a comfortable pitch level while masking with white noise at 100 db SPL was presented binaurally through a pair of TDH 39 earphones with MX-41/AR cushions. The source of the masking noise was a Grason-Stadler White Noise Generator (Model 455-B) which was coupled to the amplifier-speaker. The output of the noise generator was fed through the amplifier-speaker to the earphones which were placed on a coupler attached to the microphone of the sound level meter. The gain control of the speaker was regulated until the masking noise produced a 100 db SPL reading. This sound was used whenever masking was presented to disrupt auditory feedback.

Since increases in vocal intensity were expected when masking was utilized (Lombard Effect), the women maintained the intensity of their phonations between 72 and 74 db SPL. This was accomplished by visually monitoring the sound level meter, set at slow speed, while performing the task. To ofset any reaction to the masking noise, the subjects were not allowed to perform the next experimental condition until they had rested a minimum

of 150 seconds (3).

(c.) Comfortable pitch-controlled intensity. Preliminary experimentation indicated that a person's attempt to control the intensity of his phonation might have an effect on the performance of vocal fold diadochokinesis. To measure this variable, the subjects were asked to follow the same procedure as in condition (b). However, no masking was used.

2. Evaluating the importance of somesthetic feedback. Subjects undergoing laryngeal anesthetization performed vocal fold diadochokinesis to determine the significance of disrupting somesthetic feedback. These persons produced the diadochokinetic task as rapidly as possible at a comfortable pitch and intensity level for three five second trials. Then the laryngologist repeatedly sprayed the subjects' larynges with four per cent cocaine to topically anesthetize the larynx. Adequate anesthetization was indicated when the laryngologist was able to probe the glottic region without a response from the patient. Then a second series of three five second trials was recorded.

b. Procedures used to study the effects of variations in pitch and intensity upon vocal fold diadocho-

kinesis. The young adult subjects performed the following tasks to enable the investigator to gather data referable to variations in pitch and intensity.

1. Comfortable pitch-varying intensity. The subjects were requested to utter the syllable [hʌ] as rapidly as possible for three five second trials using a comfortable pitch and intensity level. Then they produced three five second trials of the diadochokinetic task at a comfortable pitch level using a softer voice and three trials using a louder voice than they had previously.

2. High pitch-varying intensity. The participants were asked to utter the task as rapidly as possible in a high pitched voice using three intensity levels: (1) low, (2) comfortable, and (3) high. Three five second trials of each of these intensity conditions were tape recorded as samples.

3. Low pitch-varying intensity. Again the subjects produced the syllable [hʌ] at the three intensity levels mentioned above. However, they phonated in a low pitched voice during the three five second trials of each of the intensity levels.

c. Procedures utilized to study the effects of aging upon vocal fold diadochokinesis. The subjects in

the young adult, mature adult, and late senescent groups performed the diadochokinetic task rapidly using only a comfortable pitch and intensity level. Three five second trials of this condition were tape recorded.

C. DATA REDUCTION

1. Calibration of Equipment

a. Calibration procedures for the graphic level recorder. An 80 db SPL 1000 cycle per second tone was used to check the accuracy of the level recorder (General Radio, Type 1304-B) response to intensity changes when the attenuator factor was held constant. Initially, the tone was fed from a beat frequency audio-generator through the amplifier-speaker into the level recorder. The graphic recorder was adjusted utilizing the attenuator dial and the calibration and damping controls until a steady continuous 80 db graph was obtained.

Then, the volume of the 1000 cycle tone was decreased four times in 10 db SPL steps. The investigator momentarily attached the output of the amplifier-speaker to the sound level meter to adjust the gain control of the former until appropriate SPL readings were obtained on the sound level meter. Each time the intensity was decreased the speaker and graphic level recorder were recoupled and

a graph was made of the new tone. A corresponding attenuation was noted on the graphic level tracings.

An additional procedure was necessary to check the attenuator of the graphic level recorder. The uninterrupted 80 db SPL 1000 cycle per second reference tone was played into the level recorder, and the attenuator dial of the machine was used to achieve ten db decreases in intensity. Appropriate intensity representations on the graphs were obtained during this procedure.

b. Calibration of the Sono-Graph. The Kay Sono-Graph (Model 6061-A) had been recently calibrated by the manufacturer and checked by the personnel of the Louisiana State University Medical Center Speech Department for frequency and intensity characteristics. No special calibration procedures were required since only relative time measurements were to be made.

2. Analysis of Rate, Periodicity, and Intensity

The previously described tape recorded samples of vocal fold diadochokinesis were fed into a graphic level recorder equipped with a forty db potentiometer. Before the graphs were made, the taped reference tone, previously described, was played through the amplifier-speaker into the level recorder. The pen deflection was adjusted to

give an intensity range from 50 to 90 db SPL. This range was adequate for the low and comfortable intensity trials. However, since some of the loud samples contained peaks of intensity greater than 90 db, the input of the graphic level recorder was attenuated 10 db giving a range of 60 to 100 db SPL.

The samples of vocal fold diadochokinesis were then transformed into graphic representations by the level recorder. The graphic recording paper (General Radio, 1521-9428), which was separated into divisions of one db per space, represented forty db. The chart speed was set at 300 divisions per minute or ten per second, and the writing speed used was twenty inches per second. The speed of the tape recorder was changed from 15 to $7\frac{1}{2}$ inches per second because the velocity of pen deflection on the graphic level recorder was found to be inadequate to indicate accurate intensity measurements when the fast speed was utilized.

Initial testing revealed that many of the subjects were able to produce the syllable [hʌ] consecutively for only three-and-one-half or four seconds because of insufficient breath. Therefore, only the first three seconds of the three trials or nine, one second samples were used in calculating the rate, periodicity, and intensity measurements. The number of peaks for the nine seconds was counted and averaged arithmetically to yield the mean rate of

syllable repetition per second for each subject's performance of the experimental conditions. The subjects' mean rates were grouped appropriately for the statistical tests designed for each experimental hypothesis.

The variability between the lowest and the highest rates of syllable repetition among nine, one second periods was the periodicity observation for each subject. These values were calculated for the subjects' performances of each condition and arranged so that their significance could be tested statistically. A zero or small range indicated periodicity of syllable repetition.

The graphic level charts were used also for specifying the intensity of the utterances. The peaks described above were measured relative to the 80 db position on the graph paper. The intensity values, expressed in decibels, were arithmetically averaged for each sample of vocal fold diadochokinesis. Group means were computed for each experimental condition utilizing the subjects' mean intensity values.

a. Reliability of the graphic level recording assessments. Reliability of the graphic level measurements was determined by comparing thirty of the original tracings with additional graphic representations of the same samples made after all of the data had been collected. Independent

assessments of the mean intensity of phonation and of the rate of vocal fold diadochokinesis were made of the first and second tracings and compared by the Pearson Product Moment Correlation formula (18, 139). The Pearson r equaled .95 in each instance. Average differences of 1.09 db (re: reference level calibrated at 80 db SPL) and of .3 repetitions per three second period were found between the first and second measurements of intensity and rate of vocal fold diadochokinesis, respectively.

b. Validity of the investigator's measurements. To determine if other persons would make similar evaluations of rate and intensity from the graphic level tracings, another observer calculated the mean intensity and the rate of diadochokinesis for thirty samples of the phonatory task. The results of two Pearson Product Moment Correlation computations (18, 139) revealed that a high degree of association existed between the observer's findings and the investigator's calculations of mean rate and mean intensity. The obtained coefficients were .94 (rate) and .99 (intensity). An average rate difference of .27 repetitions per three second period was noted. The intensity calculations differed .22 db (re: reference level calibrated to 80 db SPL).

3. Analysis of the Pattern of Vocal Fold Diadochokinesis

Sound spectrograms were made of five hundred of the previously described tape recorded samples of vocal fold diadochokinesis utilizing a Kay Sono-Graph. Due to the time and expense involved in this procedure, a spectrogram was made of only one of the three tape recorded trials for each experimental condition. Therefore, it was necessary to select the sample which was most representative of a subject's performance. The trial containing the median rate per three second period was utilized. It was felt that the median trial would be the best choice because the mean would be affected by the extreme scores. When two or three median trials of equal rate occurred, the trial to be used was selected randomly.

Two observations to analyze the pattern of vocal fold diadochokinesis were made using the spectrograms. The first involved noting the percentage of syllables in which abduction took place. The investigator determined the presence of vocal fold abduction by observing when friction fill was present on the spectrograms during the utterance of the [h] sound. If a continuous band of sound energy were evident between the vowel formants, abduction was not indicated. In Appendix B is found an illustration of this phenomenon. Percentages were derived representing the proportion of abducted syllables in relation to the total number of expected syllables occurring during each subject's

performance of the experimental conditions. These mean percentages of abducted syllables were then arranged to facilitate computation of the statistics used to test the significance of the experimental treatments.

Only those spectrograms in which 100 per cent abducted syllables were observed were utilized to make the second pattern measurement, the percentage of phonation time during the performance of the phonatory task. Only eight of the comfortable pitch and intensity samples contained 100 per cent abduction. These samples were to be used as controls for the statistical comparisons concerning percentage of phonation time data referable to auditory feedback, pitch and intensity, and aging. To provide an equal number of phonation time observations for the other experimental treatments, eight subjects' spectrograms containing 100 per cent abducted syllables were selected at random for each experimental condition. A percentage was computed for each syllable present on these spectrograms. This figure represented the period of phonation time in relation to the total time required to utter the syllable. The mean percentage of phonation time present on each subject's spectrogram was then calculated. These percentages, grouped according to the treatment conditions, provided data for further computations to determine whether the phonation period was significantly altered by the experimental variables.

Fourteen of the twenty spectrograms made of the samples of vocal fold diadochokinesis before and after somesthetic feedback was disrupted contained 100 per cent abducted syllables. The method utilized in computing the phonation measurements of these samples was the same as described above.

a. Reliability of the measurements of the percentage of abducted syllables. The investigator independently measured thirty randomly selected spectrograms twice to obtain data to evaluate the reliability of the percentage of abducted syllable assessments. There was a ten month period between the first and second measurements. The Pearson Product Moment Correlation formula (18, 139) was utilized to compare the assessments. The r of .74 indicated that there was a high correlation between the valuations. The average difference between the first and second measurements was 11.10 per cent.

b. Validity of the measurements of the percentage of abducted syllables. When the initial measurements were made, the investigator and another observer calculated the percentage of abducted syllables present on thirty of the spectrograms which were selected at random. This observation represented the number of syllables in which abduction occurred in relation to the total number of

expected syllables. The Pearson r (18, 139) computed to compare these measurements was .92. An average difference of .58 per cent was calculated for the two persons' assessments.

c. Reliability of the measurements of the duration of the phonated portion of the syllables. Reliability of the measurements of the duration of phonation was determined by comparing two independent measurements of thirty randomly selected diadochokinetic syllables. The investigator made the first calculations immediately after the data was collected and the second ten months later. The r of .76, resulting when a Pearson correlation coefficient (18, 139) was computed, indicated that there was a marked relationship between the two assessments. The average difference between the sixty values was 11.04 per cent.

d. Validity of the measurements of the duration of the phonated portion of the syllables. When beginning to analyze the experimental data, thirty syllables, selected at random from the spectrograms containing 100 per cent abduction, were measured independently by the investigator and another observer. The percentage of phonation time in proportion to the total time required to utter each syllable was then calculated. There was a high correla-

tion (18, 139) between the two persons' observations (r = .89). The average difference between the assessments was 4.42 per cent.

4. Analysis of Pitch

Since one of the purposes of this investigation was to assess the effect of variations of pitch upon vocal fold diadochokinesis, it was considered necessary to analyze the tape recorded utterances so that the mean pitch of the samples, expressed in cycles per second, could be reported. The vocalizations were played through the tape recorder and speaker while the output of a beat frequency audio-generator was fed into a second speaker. These procedures allowed the experimenter to listen to the recorded samples while attempting to match the person's pitch with pure tones produced by the audio-generator. Pitch observations were obtained for the subjects' three trials of each experimental condition. These observations were averaged to yield a subject's mean pitch per experimental treatment. Then pitch means were computed by averaging the subject means for each experimental condition.

a. Reliability of the matching procedure. To measure the reliability of the experimenter's pitch

estimates utilizing the matching method, two independent assessments were made of the pitch of thirty-three taped samples of vocal fold diadochokinesis. The Pearson (18, 139) r of .99, computed by comparing these measurements, revealed that the investigator was highly consistent in estimating the pitches of the phonations. The average difference between the first and second assessments was 2.4 cycles per second.

b. Validity of the pitch measurements. To establish the validity of the matching procedure, thirty samples were submitted to analysis utilizing the Kay Sono-Graph. This instrument, equipped with a harmonic wave generator fed by a 500 cycle per second tone, permitted spectrum analysis to be performed on the thirty spectrograms (See Calibration of Sono-Graph). The resulting fundamental frequency for each sample, expressed in cycles per second, was compared with the thirty values found by the matching procedure using the Pearson Product Moment Correlation formula (18, 139). The results of this computation (r = .98) indicated that the matching method was a valid way to measure the pitch of the samples. The average difference between the results of the two procedures was 17 cycles per second.

CHAPTER IV

RESULTS

The purpose of the present investigation was to study the nature of vocal fold diadochokinesis utilizing repetitive productions of the syllable [hʌ] and the effects of pitch and intensity and of aging upon the rate, periodicity, and pattern of this phonatory task. Procedures followed in selecting subjects and in collecting the data were described in Chapter III.

Primary rate, periodicity, and pattern data were obtained regarding the nature of vocal fold diadochokinesis and the effects of variations in pitch and intensity and of aging upon the phonatory task. Graphic level tracings and spectrograms of the diadochokinetic samples were analyzed to secure this information. Secondary data, pitch and intensity assessments, were also procured from these graphic representations. The numerical results were rounded to the nearest hundredth.

Hypotheses formulated relative to the purpose of the study were presented in Chapter II. The methods of analyzing the data to test these hypotheses and the results of the tests are reported below.

In most instances parametric methods were employed

to determine the significance of the results. However, non-parametric procedures were used when measurements were not considered adequate to satisfy the assumptions implicit in parametric methodology.

To balance the probability of making either a Type I or a Type II error, the 5 per cent level of confidence was used to denote statistical significance. All proportional statistics were tested against an arcsin transformation of the absolute scores to check their validity (47, 448). Since the absolute scores were not significantly different from the transformed scores, only the proportional statistics are reported.

A. PRIMARY DATA

1. Nature of Vocal Fold Diadochokinesis

a. Effect of disruption of auditory feedback upon vocal fold diadochokinesis. The investigator measured the rate, periodicity, and pattern of vocal fold diadochokinesis (1) when the forty young adult subjects phonated the task at comfortable pitch and intensity levels, (2) when they utilized a comfortable pitch level, controlled intensity, and were presented with binaural masking noise to disrupt auditory feedback, and (3) when they used a comfortable pitch level but controlled intensity. Mean

intensity values, which indicated that intensity was usually maintained within the limits set for conditions (2) and (3), are presented in Appendix B.

1. Rate. To provide for comparisons of obtained rates of syllable repetition relative to the three treatments, the rates of the performances of forty young adult subjects are shown in Figure 1. A treatment-by-subject analysis of variance design (29, 156) was used to evaluate differences in rate among the treatments which were designed to determine the effects of the disruption of auditory feedback. These results are summarized in Table I. Inspection of these data reveals an F ratio which is statistically significant at the .01 level.

Since the F ratio was significant, t-tests of paired observations (27, 108) were computed to discover which of the individual treatment means were different. The results of these calculations are presented in Table II. It can be seen from the computed t in each case that the mean rates for the masking treatment were significantly slower at the .01 level than the mean rates for the other treatments. Moreover, the subjects' attempt to control intensity was not found to significantly affect the rates of vocal fold diadochokinesis. It was concluded from

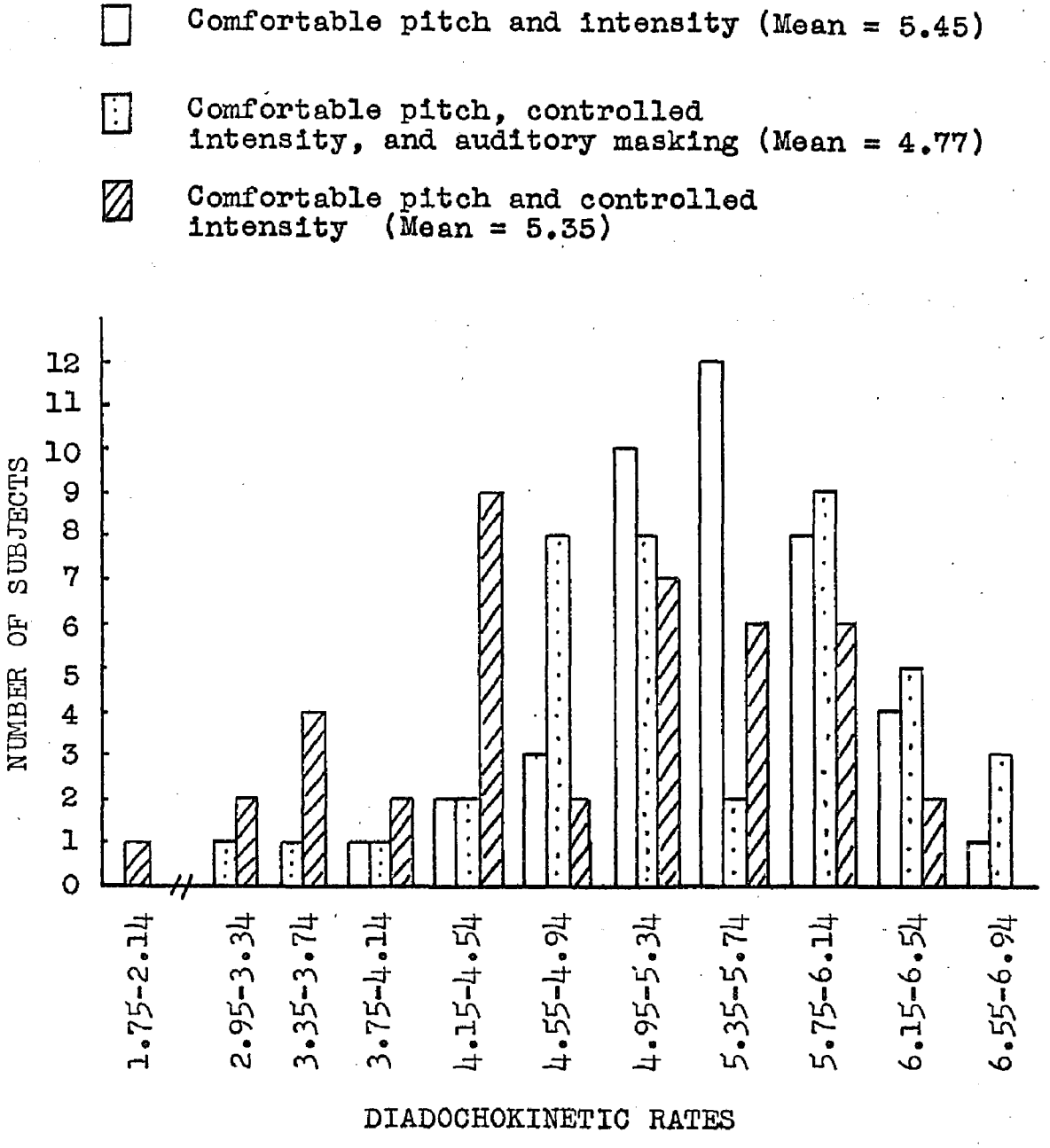

Figure 1. Rates (per second) when vocal fold diadochokinesis was produced by forty young adult women to evaluate the effect of disrupting auditory feedback.

TABLE I

SUMMARY OF AN ANALYSIS OF VARIANCE EVALUATING THE EFFECT OF DISRUPTING AUDITORY FEEDBACK ON THE RATE OF VOCAL FOLD DIADOCHOKINESIS WHEN THE TASK WAS PERFORMED BY FORTY YOUNG ADULT FEMALES UNDER CONDITIONS OF (1) COMFORTABLE PITCH AND INTENSITY, (2) COMFORTABLE PITCH, CONTROLLED INTENSITY, AND AUDITORY MASKING, AND (3) COMFORTABLE PITCH AND CONTROLLED INTENSITY

SOURCE	df	ms	F
Subjects	39	1.42	
Treatments	2	5.52	16.49*
Error	78	.33	
Total	119		

*Significant at the .01 level ($F_{(.01),\ 2,\ 78} = 4.97$).

TABLE II

SUMMARY OF THE t-TESTS EVALUATING THE EFFECT OF DISRUPTING AUDITORY FEEDBACK ON THE RATE OF VOCAL FOLD DIADOCHOKINESIS AS PRODUCED BY FORTY YOUNG ADULT WOMEN

TREATMENTS BEING COMPARED	t
Comfortable pitch and intensity versus Comfortable pitch and controlled intensity	1.04
Comfortable pitch and intensity versus Comfortable pitch, controlled intensity, and auditory masking	-4.33*
Comfortable pitch and controlled intensity versus Comfortable pitch, controlled intensity, and auditory masking	-4.33*

*Significant at the .01 level ($t_{(.01),\ 39} = 2.03$).

these results that the disruption of auditory feedback produced significant reductions in the rate of vocal fold diadochokinesis.

2. Periodicity. The periodicity values for the forty young adult subjects' performances of the three experimental treatments designed to test the role of auditory feedback during vocal fold diadochokinesis are found in Figure 2. Differences in the data were evaluated by a treatment-by-subject analysis of variance design (29, 156). In Table III is shown the result of this statistical analysis. The F ratio failed to approach significance. On the basis of this value, it was inferred that the periodicity of the phonatory task was not affected by disruption of auditory feedback.

3. Pattern

(a.) Percentage of abducted syllables. Since controlling intensity did not significantly affect either the rate or the periodicity of vocal fold diadochokinesis (See Tables II and III), the effect of disrupting auditory feedback on the percentage of abducted syllables was evaluated by comparing only the comfortable pitch and intensity and the masking samples produced by the forty young adult subjects. In Figure 3 are shown the percentages

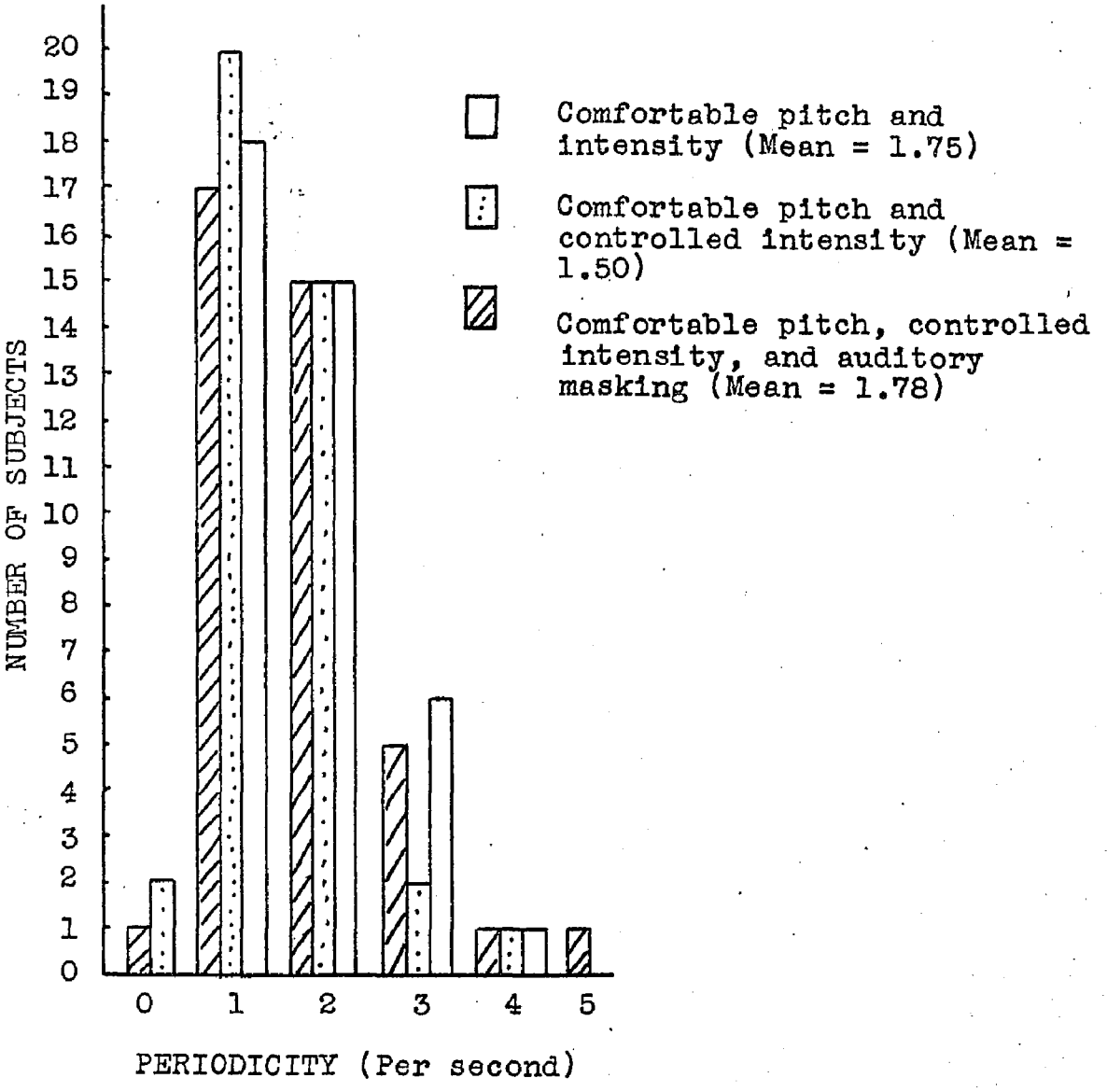

Figure 2. Periodicity values when vocal fold diadochokinesis was produced by forty young adult women to evaluate the effect of disrupting auditory feedback.

TABLE III

SUMMARY OF AN ANALYSIS OF VARIANCE EVALUATING THE EFFECT OF DISRUPTING AUDITORY FEEDBACK ON PERIODICITY OF VOCAL FOLD DIADOCHOKINESIS WHEN THE TASK WAS PERFORMED BY FORTY YOUNG ADULT FEMALES UNDER CONDITIONS OF (1) COMFORTABLE PITCH AND INTENSITY, (2) COMFORTABLE PITCH, CONTROLLED INTENSITY, AND AUDITORY MASKING, AND (3) COMFORTABLE PITCH AND CONTROLLED INTENSITY

SOURCE	df	ms	F
Subjects	39	.91	
Treatments	2	.92	1.42
Error	78	.65	
Total	119		

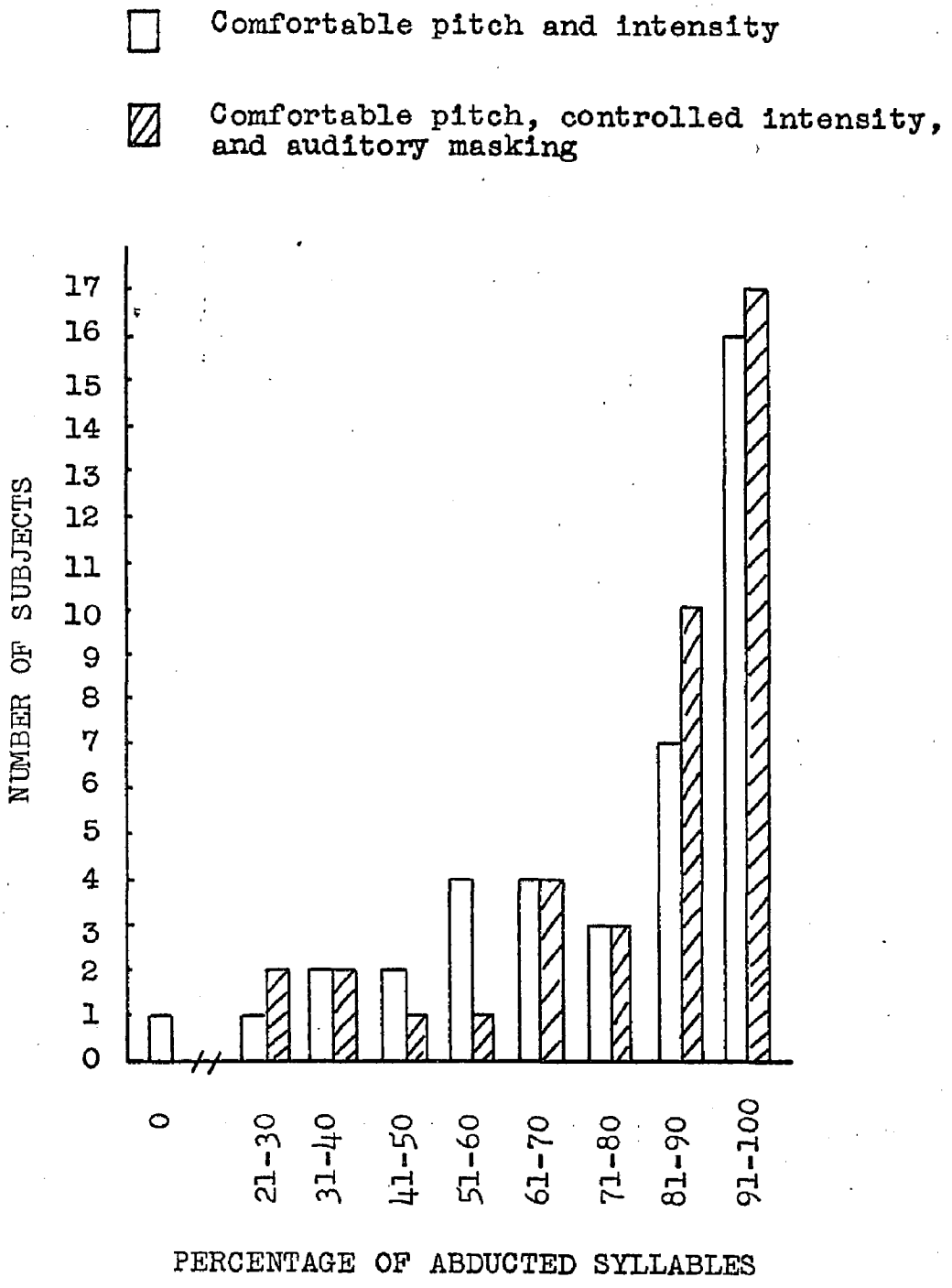

Figure 3. Percentage of abducted syllables when vocal fold diadochokinesis was produced by forty young adult women to evaluate the effect of disrupting auditory feedback.

of abducted syllables occurring during these experimental conditions. The t-test of paired observations (27, 108) was used to evaluate differences between each subject's percentage as calculated for the two treatments. This statistic, reported in Table IV, was not found to be significant. The t value made it apparent that the percentage of syllables for which vocal fold abduction occurred was not affected by disruption of auditory feedback.

(b.) Percentage of phonation time. Some of the comfortable pitch and intensity and masking samples of vocal fold diadochokinesis performed by the young adult subjects were used to obtain data regarding differences in the percentage of phonation time associated with disruption of auditory feedback. Measurements of the percentage of phonation time for the comfortable pitch and intensity condition were made of the eight samples having 100 per cent abducted syllables. Eight samples in which 100 per cent abducted syllables were observed were randomly selected to obtain phonation time measurements for the masking treatment. The percentages of phonation time are presented graphically in Figure 4. The t test for differences between the means of small independent samples (18, 224) was employed to evaluate the signifi-

TABLE IV

SUMMARY OF THE t-TEST EVALUATING THE EFFECT OF DISRUPTING AUDITORY FEEDBACK ON THE PERCENTAGE OF ABDUCTED SYLLABLES WHEN VOCAL FOLD DIADOCHOKINESIS WAS PRODUCED BY FORTY YOUNG ADULT WOMEN

TREATMENTS BEING COMPARED	t
Comfortable pitch and intensity versus Comfortable pitch, controlled intensity, and auditory masking	.34

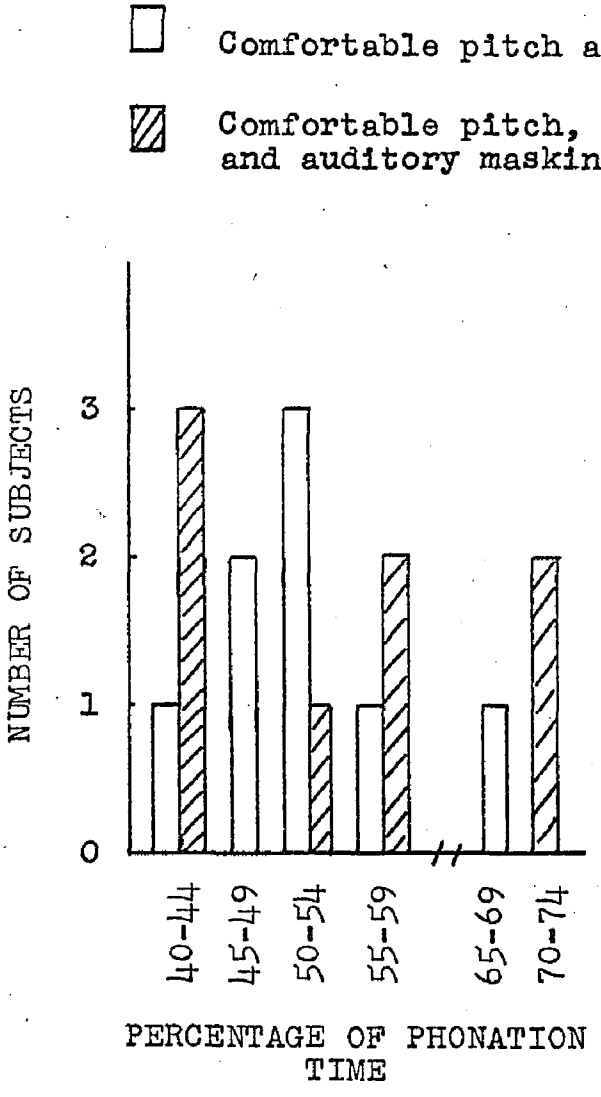

Figure 4. Percentage of phonation time when vocal fold diadochokinesis was produced by (1) eight young adult women using a comfortable pitch and intensity level and (2) eight young adult women using a comfortable pitch level, but controlling intensity while auditory masking was presented to disrupt auditory feedback.

cance of these data. The means and standard deviations of the observations and the t value are summarized in Table V. The t indicated that there were no significant differences in phonation time when masking was and was not presented. Percentage of phonation time, therefore, was not changed when auditory feedback was disrupted.

b. Effect of disrupting laryngeal somesthetic feedback upon vocal fold diadochokinesis. Rate, periodicity, and pattern measurements of samples of the phonatory task, recorded before and after ten subjects underwent topical anesthetization of the larynx, were utilized for the following statistical analyses. The phonatory task was performed at comfortable pitch and intensity levels. The pitch and intensity data for each subject and secondary information referable to these variables are found on pages 101-106.

1. Rate. In Figure 5 are shown the rates as vocal fold diadochokinesis was performed by ten subjects before and after laryngeal somesthetic feedback was disrupted. The differences in the rates were evaluated by a t-test of paired observations (27, 108). This statistical procedure was chosen because the individuals served as their own controls in the experiment. The statistical result is reported in Table VI. The t value failed to

TABLE V

SUMMARY OF THE MEANS, STANDARD DEVIATIONS, AND t-TEST EVALUATING THE EFFECT OF DISRUPTING AUDITORY FEEDBACK UPON THE PERCENTAGE OF PHONATION TIME WHEN VOCAL FOLD DIADOCHOKINESIS WAS PRODUCED BY (1) EIGHT YOUNG ADULT WOMEN USING A COMFORTABLE PITCH AND INTENSITY LEVEL, AND (2) EIGHT YOUNG ADULT WOMEN USING A COMFORTABLE PITCH LEVEL, BUT CONTROLLING INTENSITY WHILE AUDITORY MASKING WAS PRESENTED

TREATMENTS	MEAN	STANDARD DEVIATION	t
(1)	52.31	8.94	-.26
(2)	53.74	12.60	

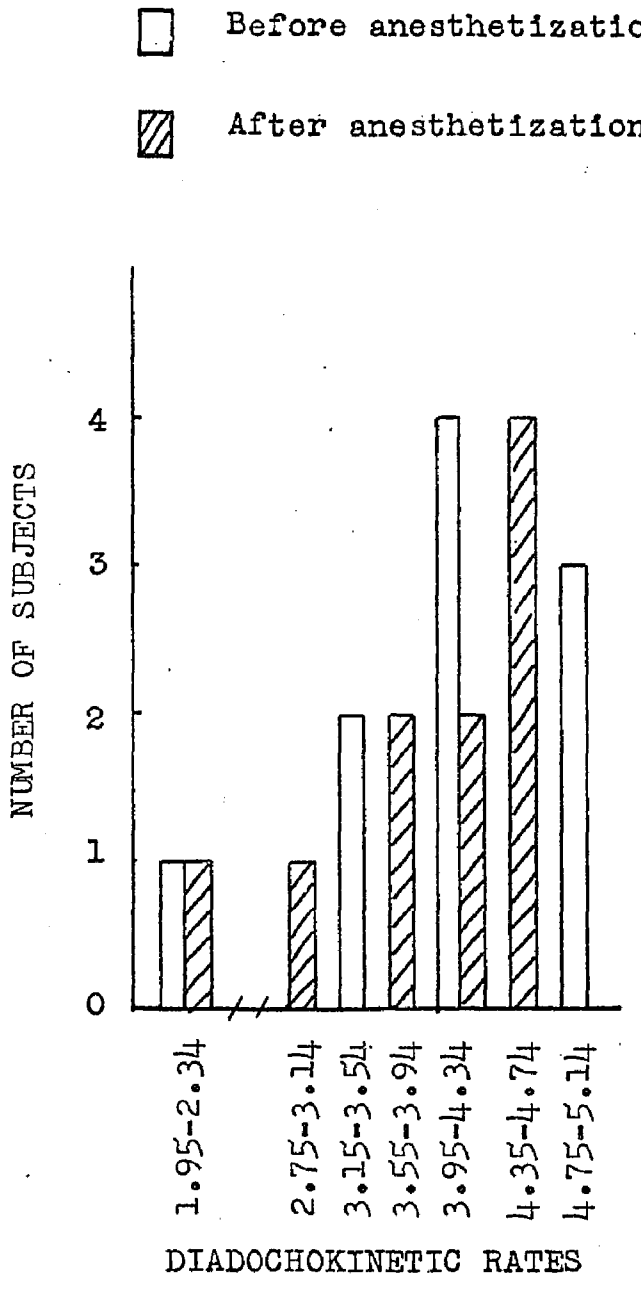

Figure 5. Rates (per second) when ten subjects produced vocal fold diadochokinesis at a comfortable pitch and intensity level before and after anesthetization disrupted laryngeal somesthetic feedback.

TABLE VI

SUMMARY OF THE t VALUES RESULTING FROM COMPARISONS OF RATE, PERIODICITY, AND PERCENTAGE OF ABDUCTED SYLLABLE MEASUREMENTS WHEN TEN SUBJECTS PRODUCED VOCAL FOLD DIADOCHOKINESIS USING A COMFORTABLE PITCH AND INTENSITY LEVEL BEFORE AND AFTER ANESTHETIZATION DISRUPTED LARYNGEAL SOMESTHETIC FEEDBACK

MEASUREMENT	t
Rate	-.30
Periodicity	.80
Percentage of abducted syllables	.98

yield significance. Therefore, it was concluded that rate of vocal fold diadochokinesis was not changed when laryngeal somesthetic feedback was disrupted.

2. Periodicity. The periodicity values observed for the experimental trials before and after topical anesthetization of the larynx are presented for inspection in Figure 6. Again, the t-test of paired observations (27, 108) was utilized in testing the significance of differences between the values.

In Table VI, page 62, are shown the results of the t-test. The t did not obtain significance. Periodicity of vocal fold diadochokinesis was not changed due to disruptions of laryngeal somesthetic feedback.

3. Pattern

(a.) Percentage of abducted syllables. The percentages of abducted syllables when the ten subjects performed vocal fold diadochokinesis before and after laryngeal anesthetization were calculated. Graphic illustration of these percentages is presented in Figure 7. The t-test of paired observations (27, 108) was utilized to compare these values. In Table VI, page 62, the insignificant result is reported. This statistic demonstrated that disruption of somesthetic feedback did

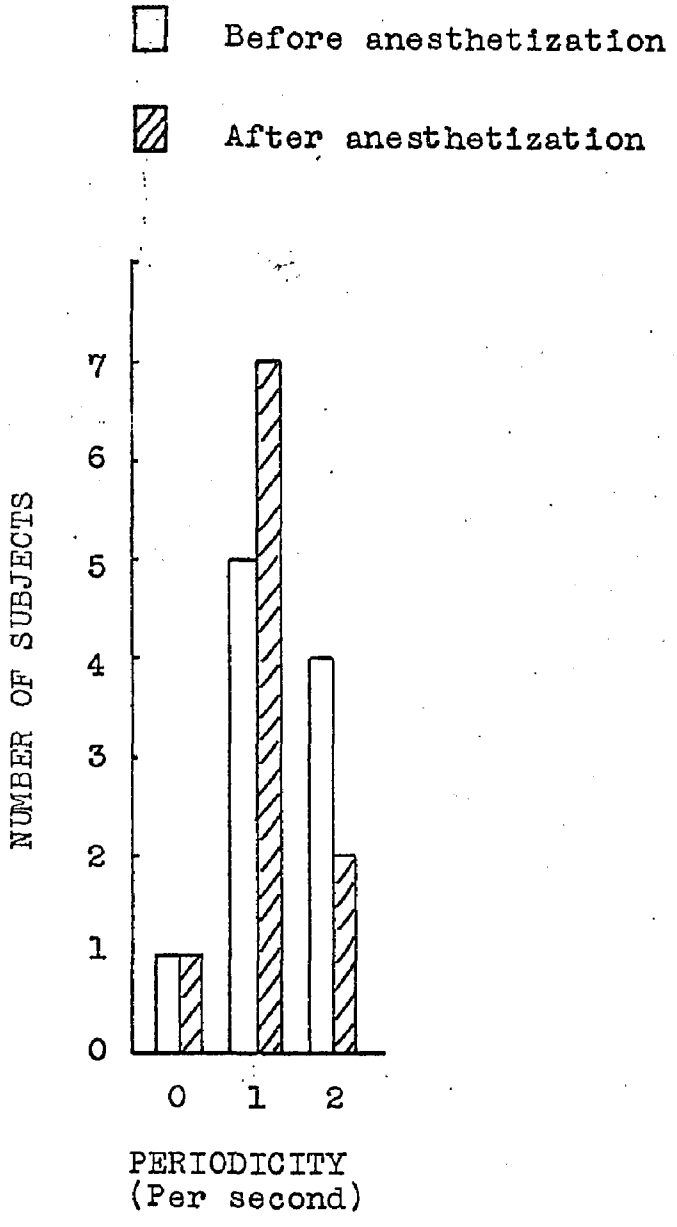

Figure 6. Periodicity values when ten subjects produced vocal fold diadochokinesis at a comfortable pitch and intensity level before and after anesthetization disrupted laryngeal somesthetic feedback.

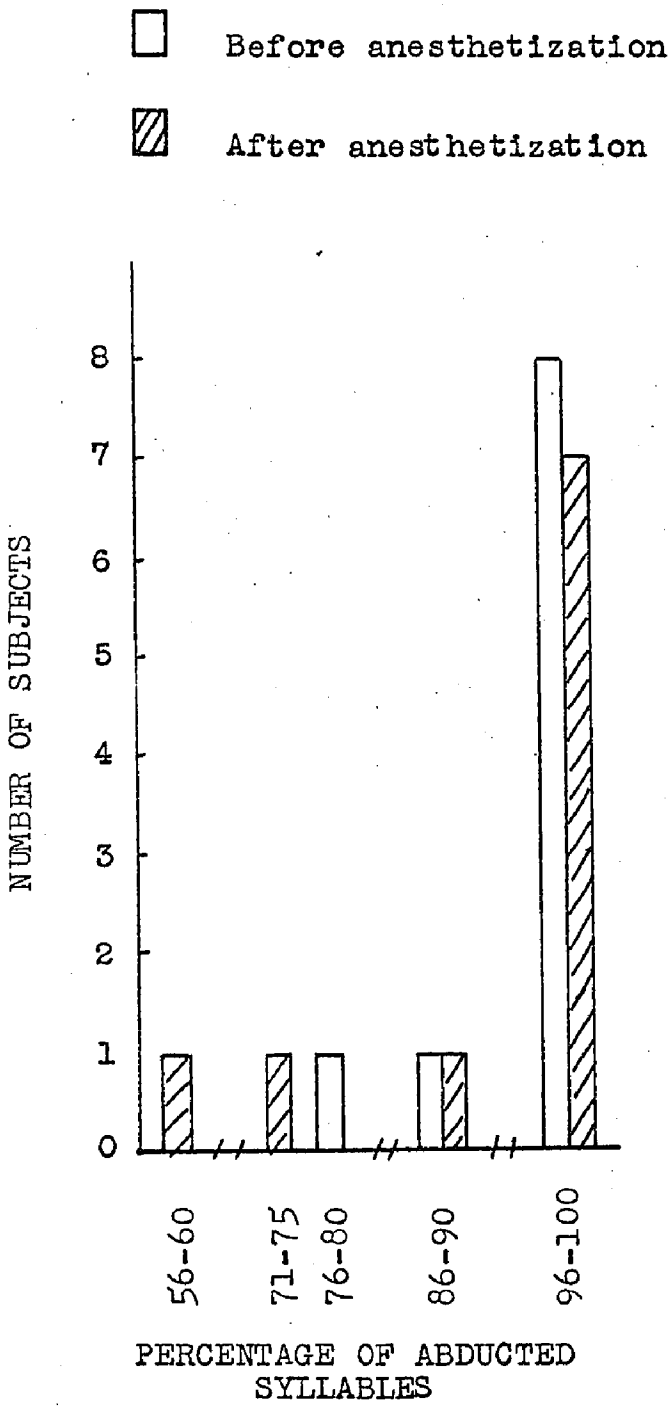

Figure 7. Percentage of abducted syllables when ten subjects produced vocal fold diadochokinesis at a comfortable pitch and intensity level before and after anesthetization disrupted laryngeal somesthetic feedback.

not affect the percentage of abducted syllables.

(b.) Percentage of phonation time. Seven of the ten subjects who underwent laryngeal anesthetization produced samples of vocal fold diadochokinesis with 100 per cent abducted syllables before and after the experimental treatment. The percentage of phonation time was assessed utilizing these samples. The percentages are shown in Figure 8. Sample size was the determining factor in selecting the Wilcoxon matched-pairs signed-ranks test (45, 75) to compare these observations. The Wilcoxon T of 4 was not significant at the .05 level. Therefore, phonation time was not affected by alterations in laryngeal somesthetic feedback.

2. Effect of Varying Pitch and Intensity upon Vocal Fold Diadochokinesis

The investigator utilized the performances of forty young adult women to study the effect of pitch and/or intensity variations on the rate, periodicity, and pattern of vocal fold diadochokinesis. The persons were instructed to regulate their phonations according to the requirement for each experimental condition. Shown in Appendix B are the means and standard deviations of the group's pitch and intensity measurements. These data indicate that the individuals were phonating at the pitch

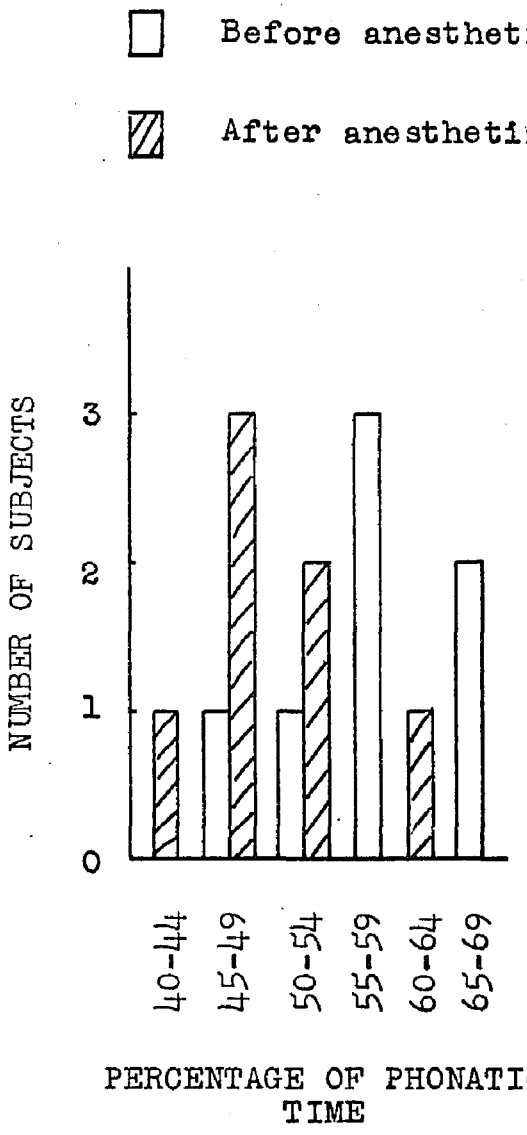

Figure 8. Percentage of phonation time when seven subjects produced vocal fold diadochokinesis at a comfortable pitch and intensity level before and after anesthetization disrupted laryngeal somesthetic feedback.

and intensity levels stipulated by the investigator.

a. Rate. A comparison of the group means of the rate measurements for the nine pitch and intensity treatments can be made by examining Figures 9 and 10. Figures which illustrate the subjects' rates of performing the diadochokinetic task during the different experimental conditions are found in Appendix A.

A treatment-by-subject analysis of variance design (29, 156) was employed to evaluate the effects of pitch and intensity upon rate measurements of the vocal fold diadochokinetic samples. In this analysis the three pitch conditions were low, comfortable, and high, and the three intensity conditions were low, comfortable, and high. The forty subjects performed the diadochokinetic task under all nine possible treatment combinations. Table VII summarizes the results of this analysis. The significant (.01) F ratio for the treatments suggested that further testing for the main effects was appropriate. Also reported in Table VII are the results of a treatment-by-treatment-by-subject analysis (29, 237) which show that pitch effects and pitch x intensity interaction were significant at the .01 level.

In addition, treatment-by-subject analyses of variance (29, 156) were computed to determine whether

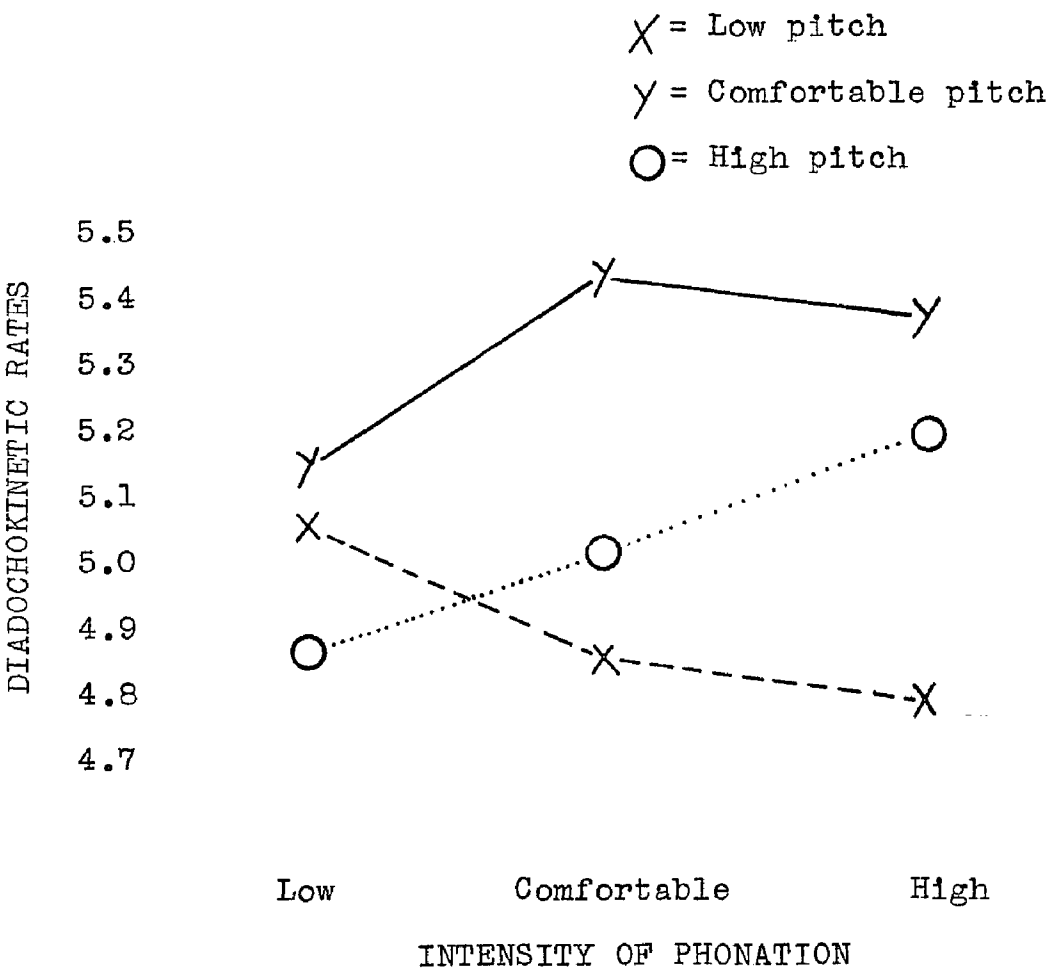

Figure 9. Mean rates (per second) of vocal fold diadochokinesis as performed by forty young adult females under three pitch conditions across three levels of vocal intensity.

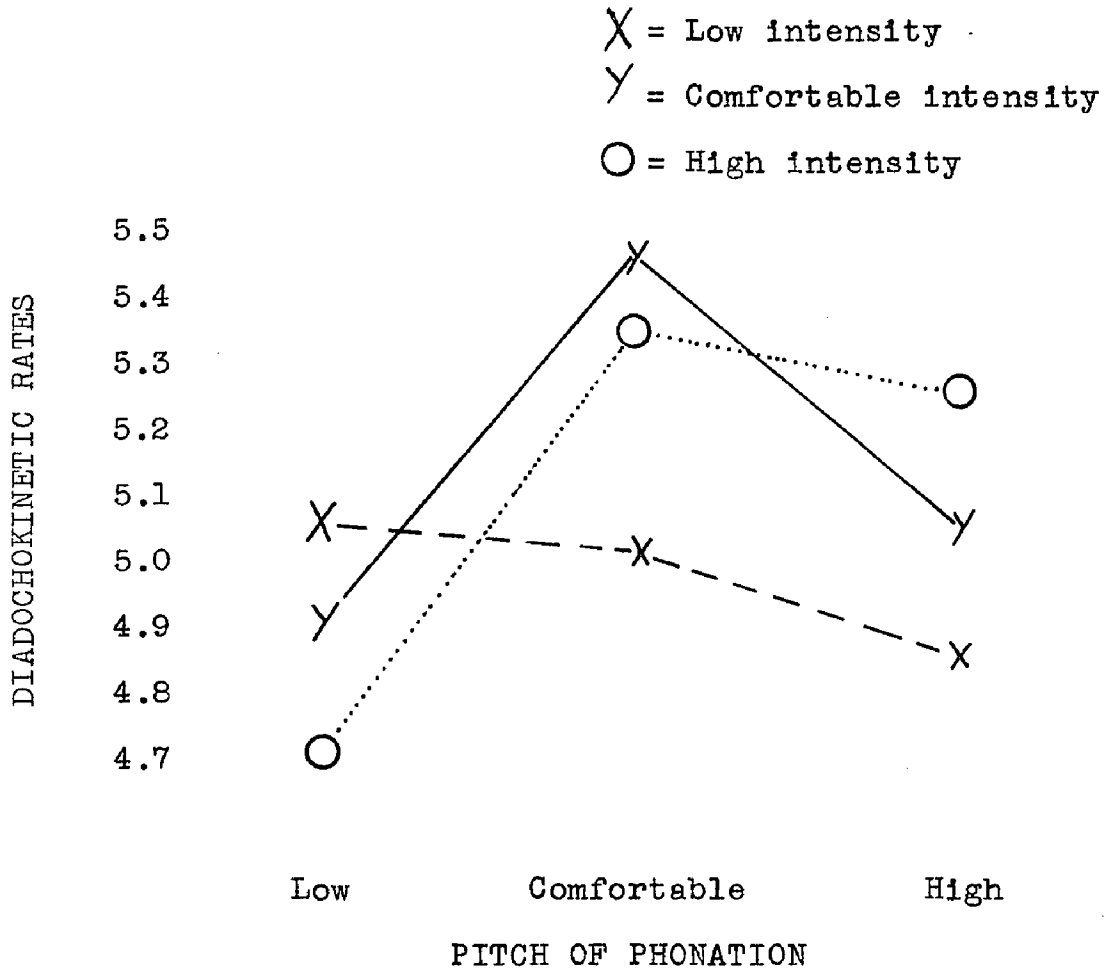

Figure 10. Mean rates (per second) of vocal fold diadochokinesis as performed by forty young adult females under three intensity conditions across three levels of vocal pitch.

TABLE VII

SUMMARY OF ANALYSES OF VARIANCE EVALUATING THE EFFECTS OF PITCH AND INTENSITY OF PHONATION ON RATES OF VOCAL FOLD DIADOCHOKINESIS AS PERFORMED BY FORTY YOUNG ADULT SUBJECTS

SOURCE	df	ms	F
	Treatment-by-Subject		
Subjects	39	3.88	
Treatments	8	2.15	8.15*
Error	312	.26	
Total	359		
	Treatment-by-Treatment-by-Subject		
Pitch	2	5.45	20.69**
Intensity	2	.47	1.80
Pitch x Intensity	4	1.33	5.07***
Total	8		

*Significant at the .01 level ($F_{(.01), 8, 312} = 2.51$).

**Significant at the .01 level ($F_{(.01), 2, 312} = 4.60$).

***Significant at the .01 level ($F_{(.01), 4, 312} = 3.32$).

there were significant differences in rate when intensity was varied at each pitch level and when pitch was altered as the three intensity levels were held constant. Table VIII summarizes these analyses. Inspection of this table reveals that F ratios significant at the .01 level were found for the high pitch-varying intensity, the comfortable intensity-varying pitch, and the high intensity-varying pitch conditions. The low pitch-varying intensity and the comfortable pitch-varying intensity treatments were significant at the .05 level, and the low intensity-varying pitch treatments failed to yield a statistically significant value.

The above significant analyses suggested that it was appropriate to test for significance between pairs of means. The results of the t ratios (18, 285) computed for this purpose are reported in Table IX. Comparisons of the following mean rates were found to be significant at the .01 level: The low pitch-low intensity/low pitch-high intensity means; the comfortable pitch-low intensity/comfortable pitch-comfortable intensity means; the high pitch-low intensity/high pitch-high intensity means; the comfortable intensity-low pitch/comfortable intensity-comfortable pitch means; the comfortable intensity-comfortable pitch/comfortable intensity-high pitch means; the high intensity-low pitch/high intensity-comfortable

TABLE VIII

RESULTS OF ANALYSES OF VARIANCE EVALUATING THE EFFECTS OF VARYING OR KEEPING PITCH OR INTENSITY CONSTANT ON THE RATES OF VOCAL FOLD DIADOCHOKINESIS AS PERFORMED BY FORTY YOUNG ADULT FEMALES

TREATMENTS	SOURCE	df	ms	F
Low pitch-varying intensity	Subjects	39	1.87	
	Treatments	2	.87	3.51*
	Error	78	.25	
	Total	119		
Comfortable pitch-varying intensity	Subjects	39	1.16	
	Treatments	2	1.15	3.83*
	Error	78	.30	
	Total	119		
High pitch-varying intensity	Subjects	39	1.58	
	Treatments	2	1.12	7.78**
	Error	78	.14	
	Total	119		
Low intensity-pitch varied	Subjects	39	1.10	
	Treatments	2	.87	2.63
	Error	78	.33	
	Total	119		
Comfortable intensity-pitch varied	Subjects	39	1.31	
	Treatments	2	3.24	13.58**
	Error	78	.24	
	Total	119		
High intensity-pitch varied	Subjects	39	1.98	
	Treatments	2	4.01	17.34**
	Error	78	.23	
	Total	119		

*Significant at the .05 level ($F_{(.05), 2, 78} = 3.15$).

**Significant at the .01 level ($F_{(.01), 2, 78} = 4.98$).

TABLE IX

SUMMARY OF DATA AND t-TESTS EVALUATING DIFFERENCES IN MEAN RATES OF VOCAL FOLD DIADOCHOKINESIS FOR THE PITCH AND INTENSITY TREATMENTS

TREATMENTS BEING COMPARED	MEAN	STANDARD DEVIATION	t
Low pitch-low intensity	5.07	.75	
versus			1.38
Low pitch-comfortable intensity	4.91	.93	
Low pitch-comfortable intensity	4.91	.93	
versus			1.23
Low pitch-high intensity	4.77	.97	
Low pitch-low intensity	5.07	.75	
versus			2.61**
Low pitch-high intensity	4.77	.97	
Comfortable pitch-low intensity	5.14	.73	
versus			2.81**
Comfortable pitch-comfortable intensity	5.46	.57	
Comfortable pitch-comfortable intensity	5.46	.57	
versus			.54
Comfortable pitch-high intensity	5.39	.95	

TABLE IX (continued)

TREATMENTS BEING COMPARED	MEAN	STANDARD DEVIATION	t
Comfortable pitch-low intensity	5.14	.73	
versus			2.27*
Comfortable pitch-high intensity	5.39	.95	
High pitch-low intensity	4.85	.81	
versus			1.65
High pitch-comfortable intensity	5.04	.78	
High pitch-comfortable intensity	5.04	.78	
versus			1.30
High pitch-high intensity	5.19	.77	
High pitch-low intensity	4.85	.81	
versus			2.94**
High pitch-high intensity	5.19	.77	
Comfortable intensity-low pitch	4.91	.93	
versus			4.78**
Comfortable intensity-comfortable pitch	5.46	.57	
Comfortable intensity-comfortable pitch	5.46	.57	
versus			3.66**
Comfortable intensity-high pitch	5.04	.78	

TABLE IX (continued)

TREATMENTS BEING COMPARED	MEAN	STANDARD DEVIATION	t
Comfortable intensity-low pitch	4.91	.93	
versus			1.12
Comfortable intensity-high pitch	5.04	.78	
High intensity-low pitch	4.77	.97	
versus			5.46**
High intensity-comfortable pitch	5.39	.95	
High intensity-comfortable pitch	5.39	.95	
versus			1.82
High intensity-high pitch	5.19	.77	
High intensity-low pitch	4.77	.97	
versus			3.65**
High intensity-high pitch	5.19	.77	

*Significant at the .05 level ($t_{(.05),\ 312} = 1.97$).

**Significant at the .01 level ($t_{(.01),\ 312} = 2.59$).

pitch means; and the high intensity-low pitch/high intensity-high pitch means. Comparison of the comfortable pitch-low intensity/comfortable pitch-high intensity means yielded a t which was significant at the .05 level. The above analyses indicate that the rate of vocal fold diadochokinesis was a function of the pitch and intensity characteristics of the phonations.

b. Periodicity. Periodicity of the samples of vocal fold diadochokinesis produced by the forty young adult subjects under the three pitch conditions across three levels of vocal intensity was measured by the investigator. The group means of the periodicity values for the pitch and intensity treatments are graphically shown in Figures 11 and 12. The subjects' periodicity values for the nine experimental conditions are found in figures located in Appendix A.

A treatment-by-subject analysis of variance (29, 156) was used to evaluate differences in periodicity due to pitch and intensity of phonation. The results of the analysis are summarized in Table X. Inspection of these data reveals an F ratio which was not significant. Therefore, further testing for main treatment effects was not appropriate. Based on this finding, it is concluded that periodicity of vocal fold diadochokinesis was not

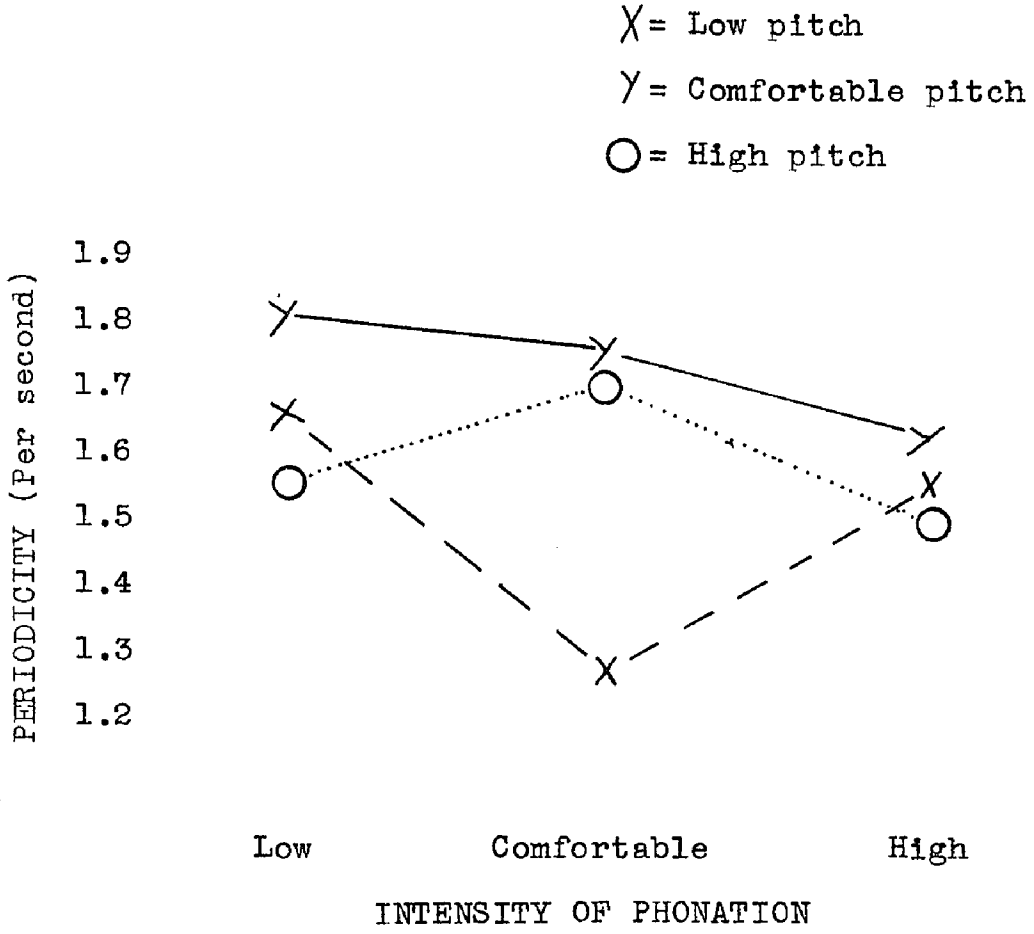

Figure 11. Mean periodicity values when forty young adult subjects produced vocal fold diadochokinesis under three pitch conditions across three levels of vocal intensity.

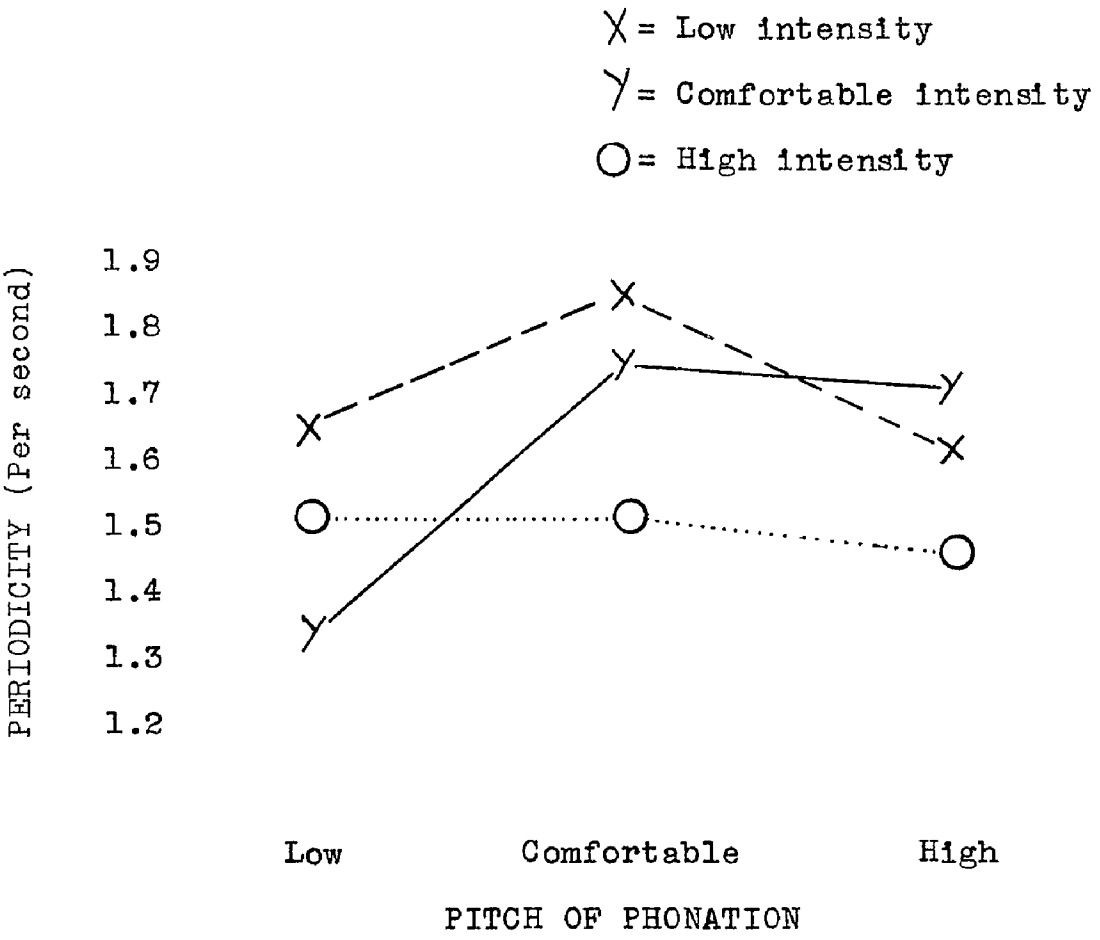

Figure 12. Mean periodicity values when forty young adult females produced vocal fold diadochokinesis under three intensity conditions across three levels of vocal pitch.

TABLE X

SUMMARY OF AN ANALYSIS OF VARIANCE EVALUATING THE EFFECT OF PITCH AND INTENSITY OF PHONATION ON PERIODICITY OF VOCAL FOLD DIADOCHOKINESIS AS PERFORMED BY FORTY YOUNG ADULT SUBJECTS

SOURCE	df	ms	F
Subjects	39	1.18	
Treatments	8	.78	1.41
Error	312	.56	
Total	359		

affected by changes in pitch and intensity.

c. Pattern

1. Percentage of abducted syllables. Measurements of the percentage of abducted syllables were obtained for the nine pitch and intensity treatments. To provide for comparison of the group means of the percentages, the data are graphically plotted in Figures 13 and 14 with either pitch or intensity as the constant. In Appendix A figures are presented to illustrate the percentages of abducted syllables as each subject performed vocal fold diadochokinesis at varying pitch and intensity levels.

Significance of the differences in the percentages of abducted syllables due to variations in pitch and intensity was evaluated using a treatment-by-subjects analysis of variance design (29, 156). Table XI presents the result of this analysis. The F ratio evaluating the nine treatment means was significant at the .01 level.

Table XI also summarizes the treatment-by-treatment-by-subject analysis of variance (29, 237) which was utilized to test the main effects of the treatments. The F ratio for pitch was significant at the .05 level. Moreover, the intensity treatment produced an F ratio which was significant at the .01 level. It can also be noticed when inspecting the table that there was not a

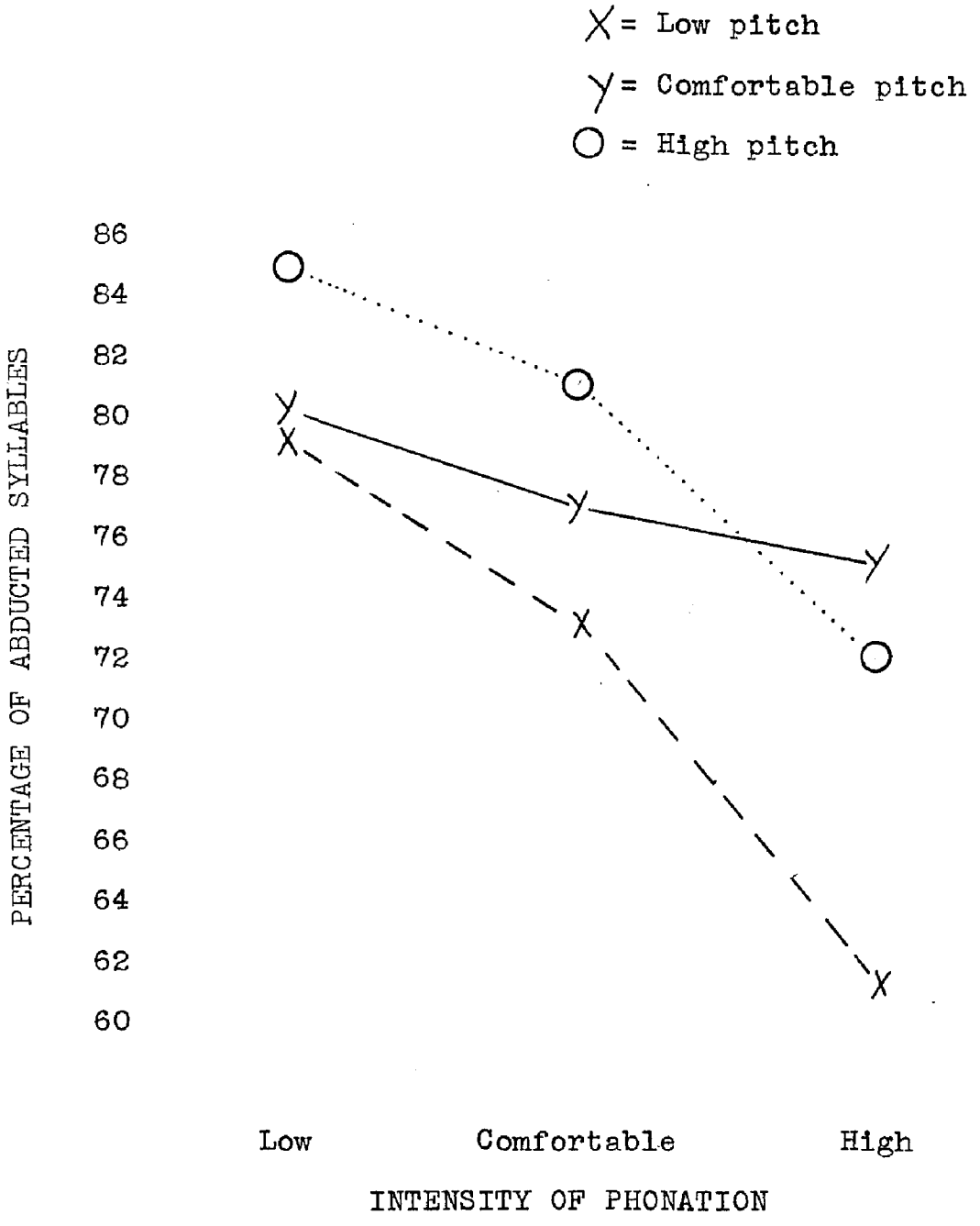

Figure 13. Mean percentage of abducted syllables when forty young adult subjects performed vocal fold diadochokinesis under three pitch conditions across three levels of vocal intensity.

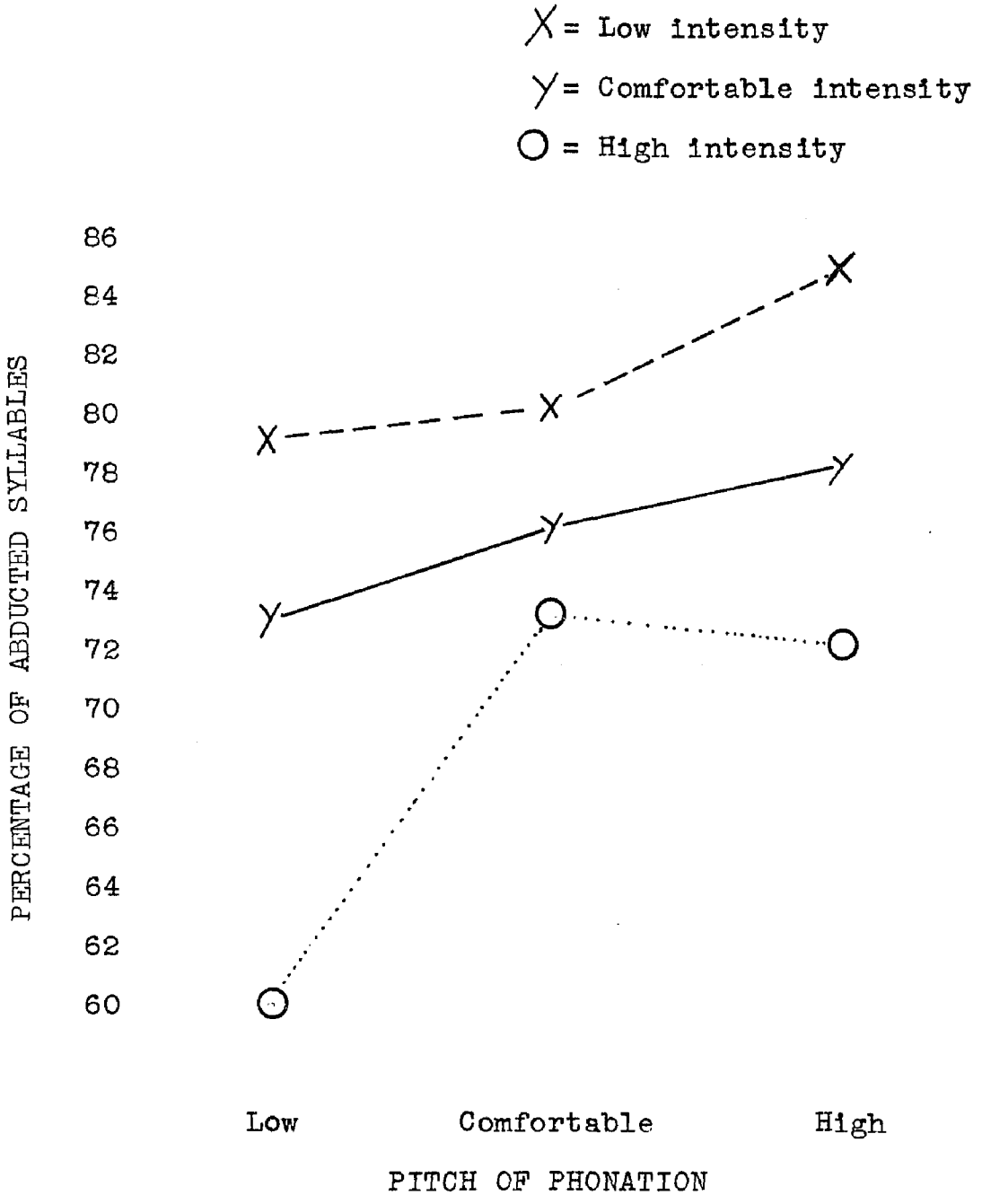

Figure 14. Mean percentage of abducted syllables when vocal fold diadochokinesis was produced by forty young adult females under three intensity conditions across three levels of vocal pitch.

TABLE XI

SUMMARY OF ANALYSES OF VARIANCE EVALUATING THE EFFECTS OF PITCH AND INTENSITY OF PHONATION ON THE PERCENTAGE OF ABDUCTED SYLLABLES WHEN VOCAL FOLD DIADOCHOKINESIS WAS PRODUCED BY FORTY YOUNG ADULT FEMALES

SOURCE	df	ms	F
	Treatment-by-Subject		
Subjects	39	2445.27	
Treatments	8	1881.37	3.74*
Error	312	503.40	
Total	359		
	Treatment-by-Treatment-by-Subject		
Pitch	2	1758.29	3.49**
Intensity	2	5106.75	10.14***
Pitch x Intensity	4	330.23	.60
Total	8		

*Significant at the .01 level ($F_{(.01), 8, 312} = 2.51$).

**Significant at the .05 level ($F_{(.05), 2, 312} = 2.99$).

***Significant at the .01 level ($F_{(.01), 2, 312} = 4.60$).

significant interaction effect between the treatments.

Treatment-by-subject analyses of variance (29, 156) were calculated to evaluate the significance of differences in the percentages of syllables abducted when intensity was varied as pitch was maintained at low, comfortable, and high levels, and when pitch was altered as subjects phonated at low, comfortable, and high levels of vocal intensity. In Table XII are shown the results of these analyses. Comparison of the percentages of abducted syllables when the phonatory task was performed in a low pitched voice across three levels of vocal intensity yielded an F ratio which was significant at the .01 level. The analysis of the percentages of abducted syllables during high pitch-varying intensity conditions was significant at the .05 level. Results of the analyses of the differences in the percentages of abducted syllables for the other experimental treatments failed to reach statistical significance. These findings show that intensity is a significant determinant in the percentage of abducted syllables during high and low pitched performances of vocal fold diadochokinesis.

Since significant differences were found in two of the preceding analyses, further testing of the six pairs of means involved seemed appropriate. Table XIII presents a summary of the t-tests (18, 285) computed to determine

TABLE XII

RESULTS OF ANALYSES OF VARIANCE EVALUATING THE EFFECTS OF VARYING OR KEEPING PITCH OR INTENSITY CONSTANT ON THE PERCENTAGE OF ABDUCTED SYLLABLES WHEN VOCAL FOLD DIADOCHOKINESIS WAS PERFORMED BY FORTY YOUNG ADULT FEMALES

TREATMENTS	SOURCE	df	ms	F
Low pitch-varying intensity	Subjects	39	1311.20	
	Treatments	2	3412.30	6.54**
	Error	78	522.00	
	Total	119		
Comfortable pitch-varying intensity	Subjects	39	1127.77	
	Treatments	2	514.45	1.14
	Error	78	450.98	
	Total	119		
High pitch-varying intensity	Subjects	39	1220.18	
	Treatments	2	1840.50	4.50*
	Error	78	408.74	
	Total	119		
Low intensity-pitch varied	Subjects	39	929.71	
	Treatments	2	323.67	.79
	Error	78	411.92	
	Total	119		
Comfortable intensity-pitch varied	Subjects	39	900.71	
	Treatments	2	512.31	1.03
	Error	78	499.74	
	Total	119		
High intensity-pitch varied	Subjects	39	1612.06	
	Treatments	2	1582.81	2.62
	Error	78	603.40	
	Total	119		

*Significant at the .05 level ($F_{(.05), 2, 78} = 3.15$).

**Significant at the .01 level ($F_{(.01), 2, 78} = 4.98$).

TABLE XIII

SUMMARY OF THE DATA AND t-TESTS EVALUATING DIFFERENCES IN MEAN PERCENTAGES OF ABDUCTED SYLLABLES FOR THE PITCH AND INTENSITY TREATMENTS

TREATMENTS BEING COMPARED	MEAN	STANDARD DEVIATION	t
Low pitch-low intensity	79.45	24.78	
versus			1.24
Low pitch-comfortable intensity	73.22	25.69	
Low pitch-comfortable intensity	73.22	25.69	
versus			2.38*
Low pitch-high intensity	61.28	32.88	
Low pitch-low intensity	79.45	24.78	
versus			3.62**
Low pitch-high intensity	61.28	32.88	
High pitch-low intensity	84.63	23.72	
versus			.85
High pitch-comfortable intensity	80.38	25.30	
High pitch-comfortable intensity	80.38	25.30	
versus			1.80
High pitch-high intensity			

TABLE XIII (continued)

TREATMENTS BEING COMPARED	MEAN	STANDARD DEVIATION	t
High pitch-low intensity	84.63	23.72	
versus			2.65**
High pitch-high intensity	71.35	29.74	

*Significant at the .05 level ($t_{(.05),\ 312} = 1.97$).

**Significant at the .01 level ($t_{(.01),\ 312} = 2.59$).

the significance of differences between these means. Inspection of this table reveals that extremes in intensity at high and at low pitches produced a significant difference (at the .01 level) in the mean percentage of abducted syllables.

2. Percentage of phonation time. The percentages of phonation time for the eight subjects having 100 per cent abducted syllables during the comfortable pitch and intensity condition were used in the following comparison. Eight subjects for whom 100 per cent abducted syllables were observed were randomly selected for each of the other eight pitch and intensity treatments. The spectrograms of the samples of vocal fold diadochokinesis produced by these subjects were measured to obtain percentages of phonation time. The group means of the phonation time percentages for the nine treatments are graphically plotted in Figures 15 and 16. The subjects' percentages of phonation time for the varied pitch and intensity conditions are enumerated in figures found in Appendix A.

A simple randomized analysis of variance (29, 340) was utilized to evaluate the significance of differences between the mean percentages of phonation time for each treatment. Table XIV presents the insignificant F ratio obtained in this analysis. This statistic reveals that the

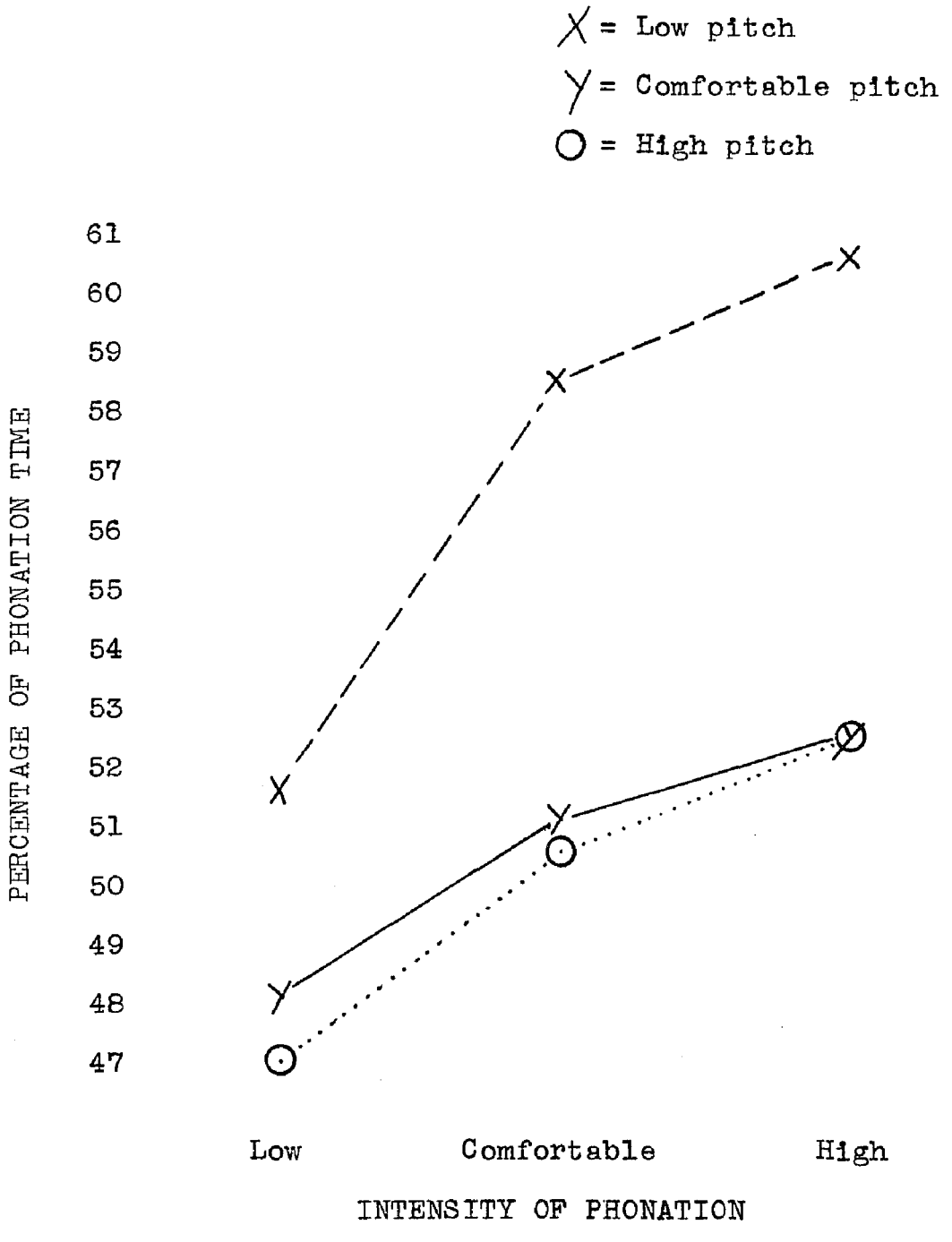

Figure 15. Mean percentages of phonation time when nine groups each including eight young adult subjects performed vocal fold diadochokinesis under three pitch conditions across three levels of vocal intensity.

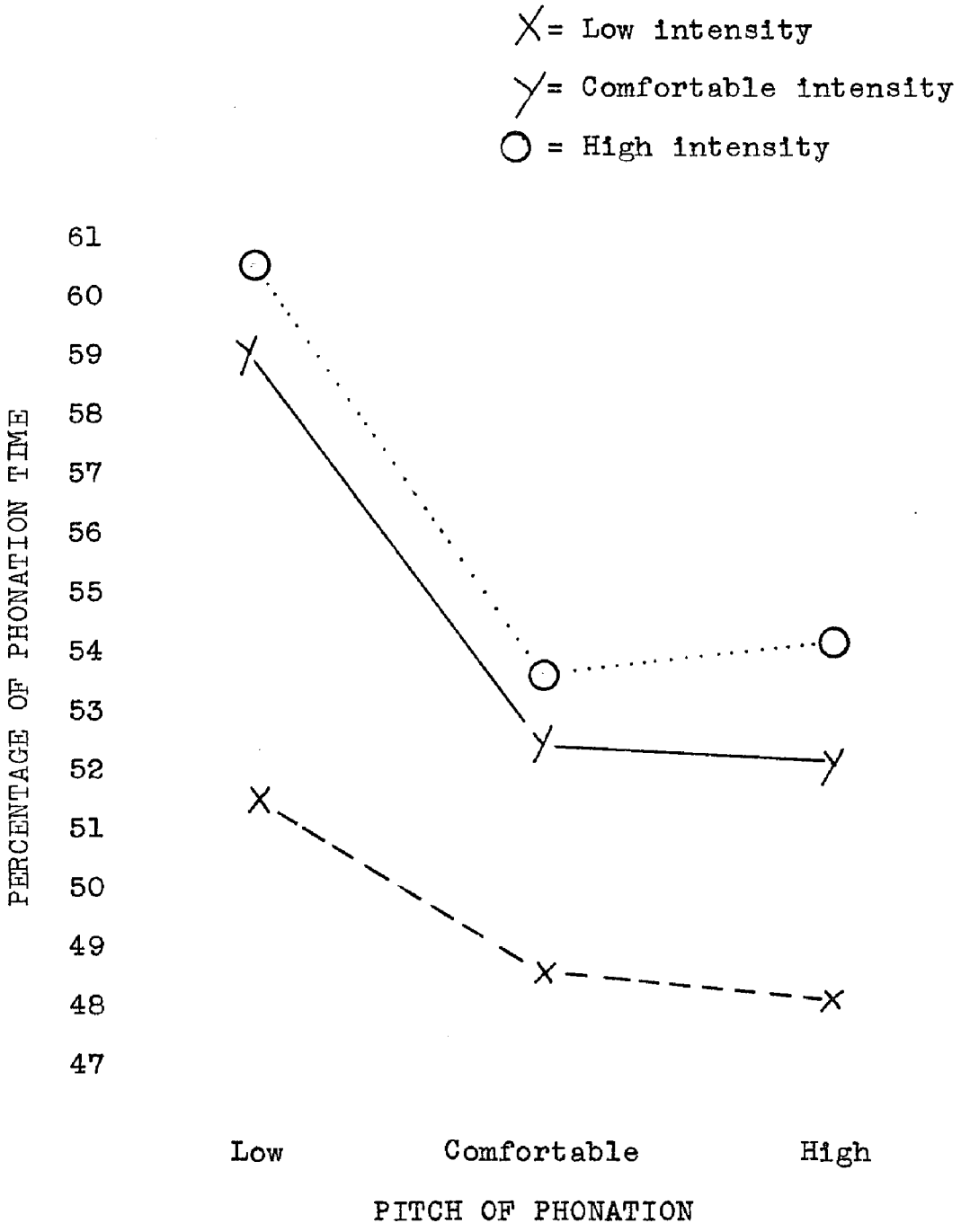

Figure 16. Mean percentages of phonation time when nine groups each including eight young adult subjects performed vocal fold diadochokinesis under three intensity conditions across three levels of vocal pitch.

TABLE XIV

SUMMARY OF AN ANALYSIS OF VARIANCE EVALUATING THE EFFECTS OF VARIATIONS IN PITCH AND INTENSITY UPON THE PERCENTAGES OF PHONATION TIME WHEN VOCAL FOLD DIADOCHOKINESIS WAS PERFORMED BY NINE GROUPS EACH INCLUDING EIGHT YOUNG ADULT SUBJECTS

SOURCE	df	ms	F
Treatments	8	156.65	2.06
Error	63	76.04	
Total	71		

percentage of phonation time was not altered significantly when pitch and intensity were varied.

3. Effect of Aging upon Vocal Fold Diadochokinesis

Comfortable pitch and intensity samples as the young adult group, mature group, and late senescent group of women performed vocal fold diadochokinesis were measured to obtain the following rate, periodicity, and pattern data. Mean pitch and intensity values, which indicated that the groups of subjects phonated the task in a similar manner, are found in Appendix B.

a. Rate. The subjects' rates for the comfortable pitch and intensity samples of vocal fold diadochokinesis are presented graphically in Figure 17. A simple randomized analysis of variance (29, 340) was used to evaluate variations in rates due to aging. Table XV summarizes the results of this procedure. The F ratio failed to reach statistical significance. On the basis of this statistic, it can be stated that rate of vocal fold diadochokinesis was not affected by the age of these female subjects.

b. Periodicity. Periodicity of the comfortable pitch and intensity samples was measured to secure further information concerning the effects of aging upon the phonatory task. Periodicity values for the subjects are

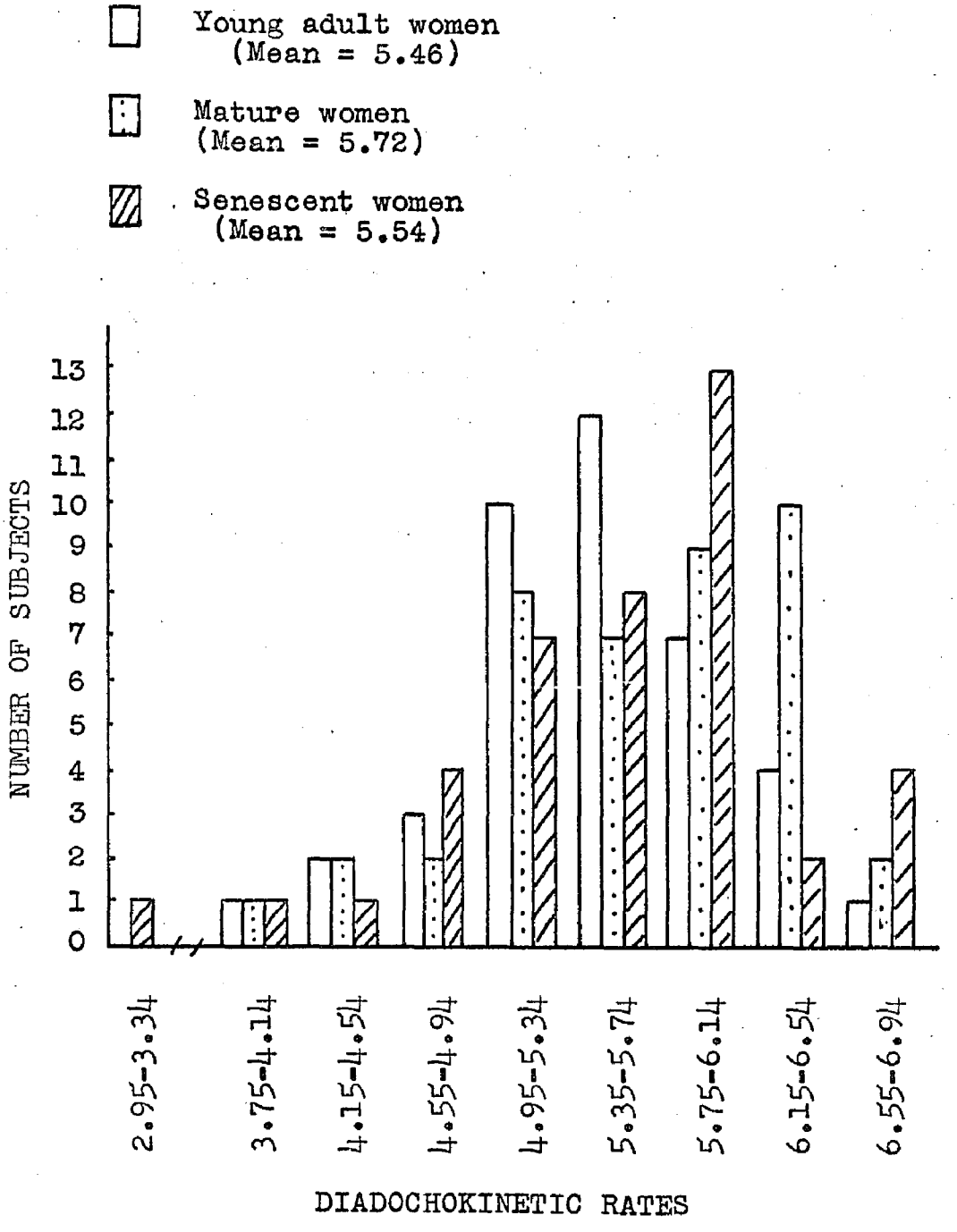

Figure 17. Rates (per second) when vocal fold diadochokinesis was produced at a comfortable pitch and intensity level by forty young adult women, forty mature women, and forty women in the late senescent period of life.

TABLE XV

SUMMARY OF AN ANALYSIS OF VARIANCE EVALUATING THE EFFECT OF AGING UPON THE RATE OF VOCAL FOLD DIADOCHOKINESIS PRODUCED AT A COMFORTABLE PITCH AND INTENSITY LEVEL BY FORTY YOUNG ADULT WOMEN, FORTY MATURE WOMEN, AND FORTY WOMEN IN THE LATE SENESCENT PERIOD OF LIFE

SOURCE	df	ms	F
Treatments	2	.72	1.65
Error	117	.43	
Total			

shown graphically in Figure 18. These observations were statistically evaluated by a simple randomized analysis of variance (29, 340). In Table XVI is presented the result of this computation. The F ratio was not found to be statistically significant. Aging, therefore, did not appear to affect periodicity of vocal fold diadochokinesis.

c. Pattern

1. Percentage of abducted syllables. The effect of aging upon the percentage of abducted syllables was ascertained by comparing assessments of the comfortable pitch and intensity samples of the phonatory task produced by young adult females, mature women, and females in the late senescent period of life. Figure 19 permits a comparison between the subjects' percentages of abducted syllables. Statistical significance of these percentages was determined by a simple randomized analysis of variance (29, 340). The results of this procedure are found in Table XVII. The insignificant F ratio indicated that aging did not affect the women's ability to abduct the vocal folds during rapid syllable production.

2. Percentage of phonation time. The investigator randomly selected spectrograms of samples of vocal fold diadochokinesis produced by eight mature subjects and

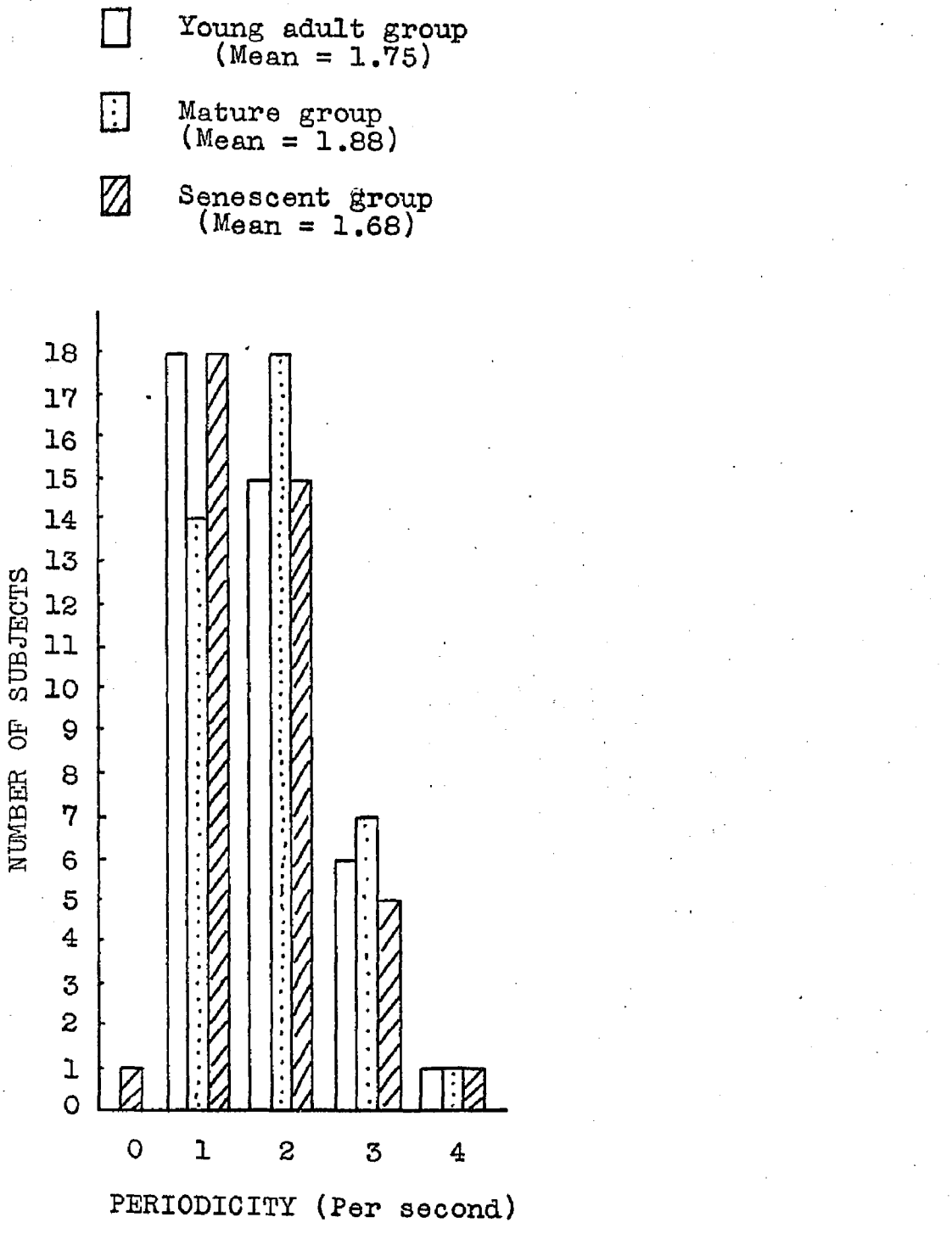

Figure 18. Periodicity values when vocal fold diadochokinesis was produced at a comfortable pitch and intensity level by forty young adult women, forty mature women, and forty women in the late senescent period of life.

TABLE XVI

SUMMARY OF AN ANALYSIS OF VARIANCE EVALUATING THE EFFECT OF AGING UPON THE PERIODICITY OF VOCAL FOLD DIADOCHOKINESIS PRODUCED AT A COMFORTABLE PITCH AND INTENSITY LEVEL BY FORTY YOUNG ADULT WOMEN, FORTY MATURE WOMEN, AND FORTY WOMEN IN THE LATE SENESCENT PERIOD OF LIFE

SOURCE	df	ms	F
Treatments	2	.41	.62
Error	117	.66	
Total	119		

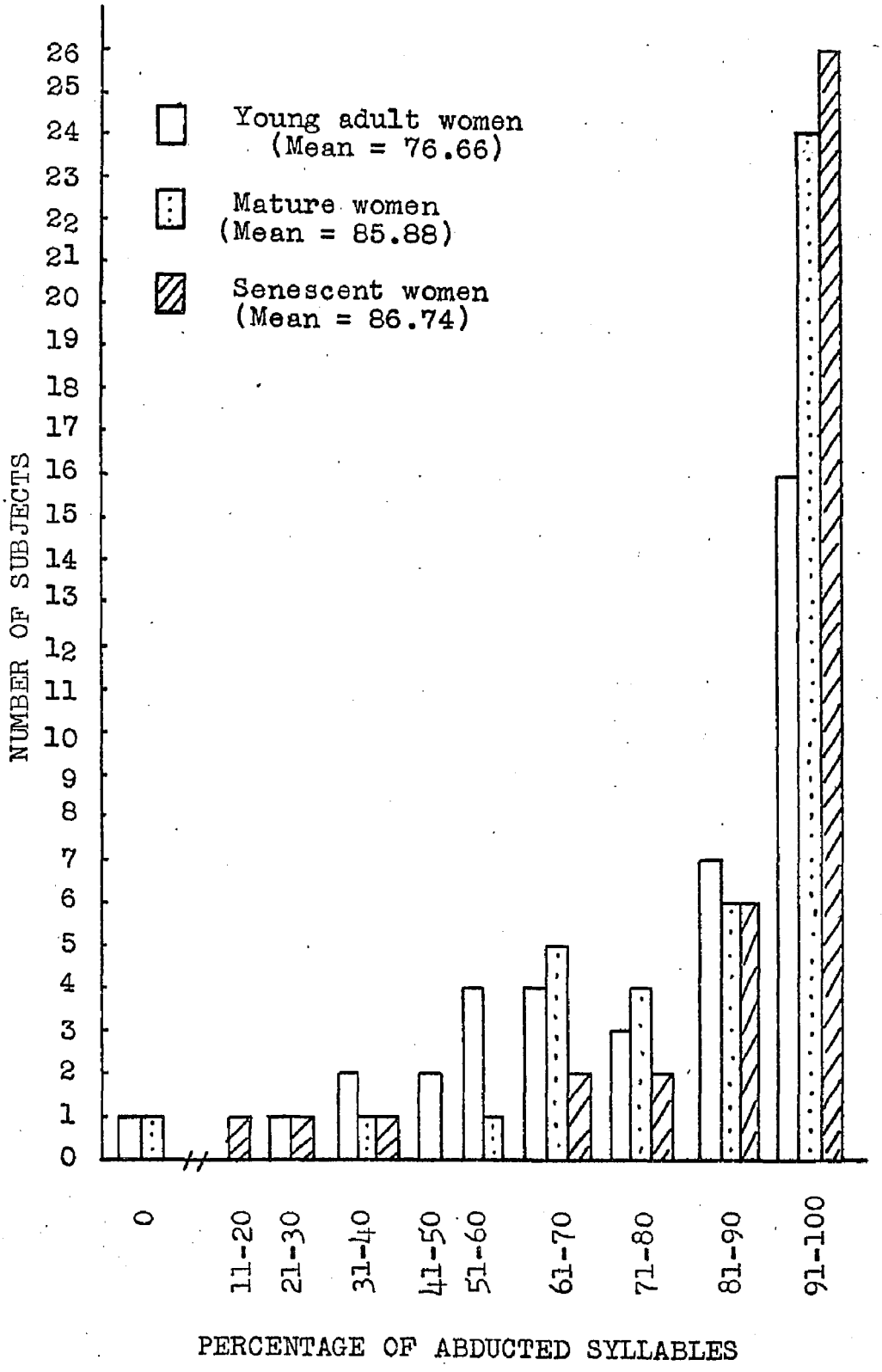

Figure 19. Percentage of abducted syllables when vocal fold diadochokinesis was produced at a comfortable pitch and intensity level by forty young adult women, forty mature women, and forty women in the late senescent period of life.

TABLE XVII

SUMMARY OF AN ANALYSIS OF VARIANCE EVALUATING THE EFFECT OF AGING UPON THE PERCENTAGE OF ABDUCTED SYLLABLES WHEN VOCAL FOLD DIADOCHOKINESIS WAS PRODUCED AT A COMFORTABLE PITCH AND INTENSITY LEVEL BY FORTY YOUNG ADULT WOMEN, FORTY MATURE WOMEN, AND FORTY WOMEN IN THE LATE SENESCENT PERIOD OF LIFE

SOURCE	df	ms	F
Treatments	2	1249.24	2.54
Error	117	491.34	
Total	119		

eight members of the senescent group in which 100 per cent abducted syllables were observed. The percentage of phonation time was measured for each subject. These values were compared with the percentages of phonation time found when the eight young adult subjects performed the task at a comfortable pitch and intensity level. The percentages for the twenty-four subjects are shown graphically in Figure 20. A simple randomized analysis of variance (29, 340) was carried out to evaluate differences among the group means. In Table XVIII is found a summary of the results of this procedure. The F ratio failed to reach a statistically significant level. Based on the above information, the phonatory pattern during rapid repetitions of the syllable did not appear to differ due to aging.

B. SECONDARY DATA

The means and standard deviations of the pitch and intensity measurements were calculated for the samples of all of the experimental conditions. The data for all treatments except somesthetic feedback are presented in Appendix B.

It can be observed in Table XIX that the pitch and intensity assessments seemed different when the subjects performed the phonatory task at a comfortable pitch and intensity level before and after somesthetic feedback was

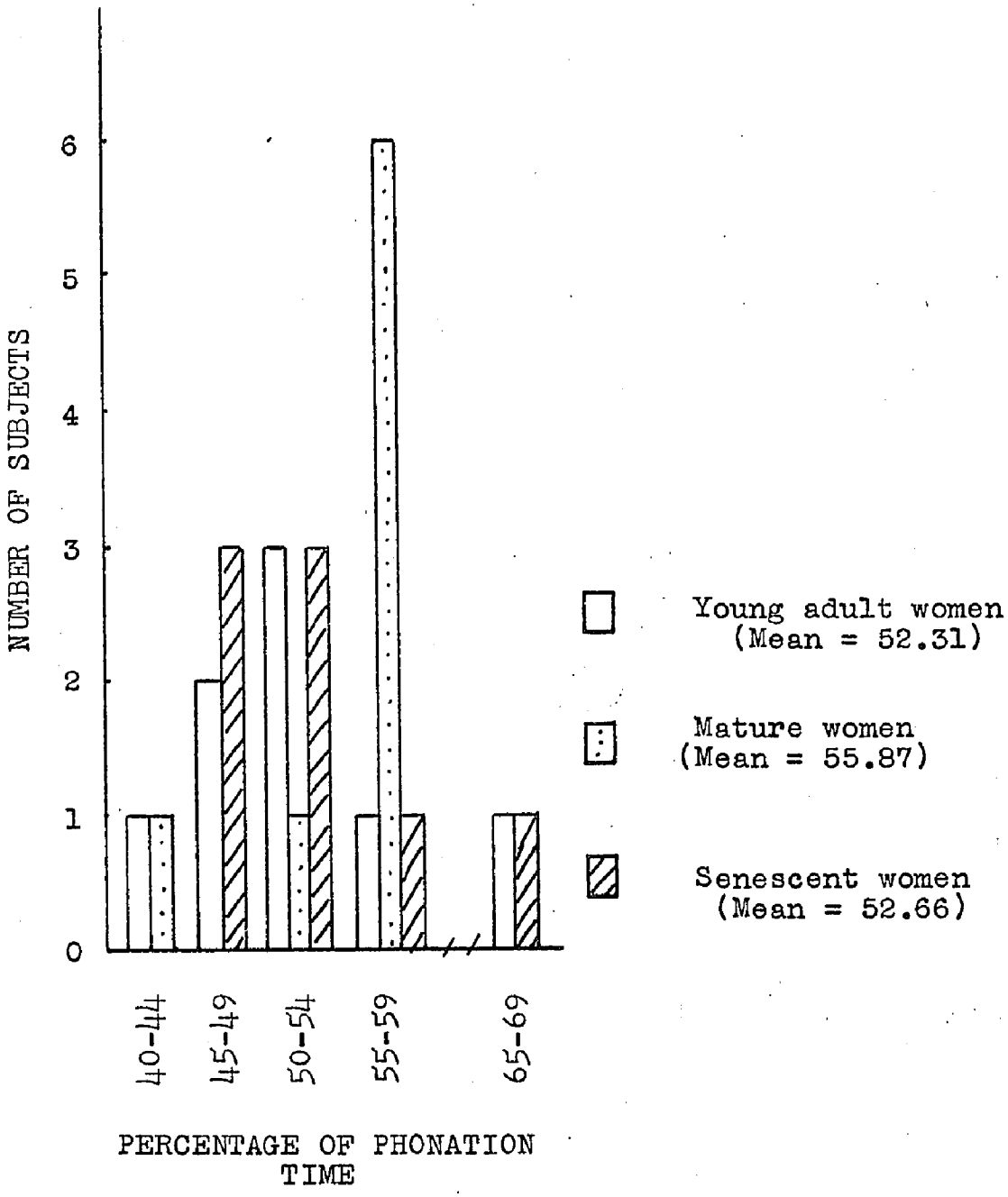

Figure 20. Percentage of phonation time when vocal fold diadochokinesis was produced at a comfortable pitch and intensity level by eight young adult women, eight mature women, and eight women in the late senescent period of life.

TABLE XVIII

SUMMARY OF AN ANALYSIS OF VARIANCE EVALUATING THE EFFECT OF AGING UPON THE PERCENTAGE OF PHONATION TIME WHEN VOCAL FOLD DIADOCHOKINESIS WAS PRODUCED AT A COMFORTABLE PITCH AND INTENSITY LEVEL BY EIGHT YOUNG ADULT WOMEN, EIGHT MATURE WOMEN, AND EIGHT WOMEN IN THE LATE SENESCENT PERIOD OF LIFE

SOURCE	df	ms	F
Treatments	2	30.78	.56
Error	21	54.46	
Total	23		

TABLE XIX

SUMMARY OF THE PITCH (CYCLES PER SECOND) AND INTENSITY (db) OF THE SAMPLES OF VOCAL FOLD DIADOCHOKINESIS PRODUCED BY THE TEN SUBJECTS WHO UNDERWENT ANESTHETIZATION TO EVALUATE THE EFFECT OF DISRUPTION OF SOMESTHETIC FEEDBACK

SUBJECT	INTENSITY BEFORE ANESTHESIA	INTENSITY AFTER ANESTHESIA	PITCH BEFORE ANESTHESIA	PITCH AFTER ANESTHESIA
1	77.33	83.37	110	120
2	66.53	66.95	134.33	129.33
3	73.61	76.05	278.66	290
4	72.45	73.15	126	126
5	73.77	74.90	132.67	125.33
6	71.72	72.94	114	114
7	73.83	79.09	208	250
8	77.27	73.50	122	126
9	75.23	77.85	124.66	130
10	81.38	82.65	210	211.33

disrupted by topical anesthetization of the larynx. T-tests of paired observations (27, 108) were computed to ascertain whether these differences were significant. The results of the calculations are reported in Table XX. The t evaluating pitch differences was not statistically significant. The t for intensity changes was found to be significant at the .10 level. Although this level of significance did not meet the requirements for statistical significance as defined for this investigation, it can be observed from inspection of the subject data that the intensity measurements for all but one subject were numerically higher after anesthetization than before anesthetization. This is suggestive that intensity of phonation was affected by laryngeal anesthetization.

TABLE XX

SUMMARY OF THE t VALUES RESULTING FROM COMPARISONS OF PITCH AND INTENSITY WHEN TEN SUBJECTS PRODUCED VOCAL FOLD DIADOCHOKINESIS USING A COMFORTABLE PITCH AND INTENSITY LEVEL BEFORE AND AFTER ANESTHETIZATION DISRUPTED LARYNGEAL SOMESTHETIC FEEDBACK

VARIABLE	t
Pitch	1.41
Intensity	2.02*

*Significant at the .10 level ($t_{(.10),\ 9} = 1.83$).

CHAPTER V

DISCUSSION

This study was designed to test hypotheses relative to the nature of vocal fold diadochokinesis as performed by adult subjects and to the effect of certain variables upon the rate, periodicity, and pattern of this phonatory task. In previous chapters the literature concerning the subject has been reviewed, the methodology has been explained, and the results of the investigation have been reported. A discussion of the results will be presented in this chapter.

A. VOCAL FOLD DIADOCHOKINESIS

For the present investigation the rapid production of the syllable [hʌ] was used as a measure of vocal fold diadochokinesis. The possibility that the vocal folds were not always abducting as the subjects performed the phonatory task was suggested after observing spectrograms of some of the diadochokinetic samples. As mentioned previously, formants for the [ʌ] sound were easily distinguished, but evidence of continuous phonation was frequently noted between these regions of vocal intensity. This phenomenon could have been interpreted by some

speech scientists as complete lack of vocal fold abduction. Such an explication would raise serious objection to the use of the phonatory task as a measure of vocal fold diadochokinesis. The writer has looked for other explanations of the spectrographic contour.

The electromyographic findings (4) mentioned in a previous chapter revealed that increases and decreases in electrical impulses of the laryngeal abductor and adductor muscles occurred nearly simultaneously. Therefore, if the vocal folds were moving rapidly and the abductor impulses were arrested swiftly, accompanied by immediate substitution of the adductor impulses, the phonatory process might not be stopped completely. The movement, however, would still be considered diadochokinetic since the essential criteria would be met: substitution of one motor impulse as the opposite impulse is arrested.

Phonetically this phenomenon could be interpreted as a group of syllables containing a voiced h sound. Kanter and West (22) have described the voiced h as a regular [h] uttered between two vowels and made with so little breath pressure and so rapid a closure of the glottis that the sound is barely perceptible. It is not known whether the repetitive production of a consonant-vowel syllable involving a voiced h requires a laryngeal diadochokinetic process.

Another explanation of the spectrographic contour could also emerge from information reported by Kanter and West (22). The authors stated that the effect of the [h] sound could result from "a dimunition of the volume of a vowel almost to a point of hiatus, followed by a rather rapid increase in volume." (22, 102) If this were the case, a diadochokinetic process might not have been taking place during some performances of the phonatory task. The subjects whose spectrograms did not indicate cessation of phonation might have listened for volume changes and accepted these alterations as syllable determinants.

Further discussion of the results of this investigation will be presented under the assumption that the rapid repetitive production of the syllable [hʌ] is an adequate measure of vocal fold diadochokinesis. However, it is suggested that the reader accept the interpretations proposed in this chapter cautiously until research can provide an indication of whether a laryngeal diadochokinetic process was operative in instances where definite cessation of phonation was not observed on spectrograms of rapid repetitive productions of the glottal fricative-vowel syllable.

B. NATURE OF VOCAL FOLD DIADOCHOKINESIS

The data reported in Chapter IV have provided

additional insight into the physiological process involved in vocal fold diadochokinesis as measured by the production of the syllable [hʌ]. It was pointed out that disruption of auditory feedback influenced the rate of performing the task.

Rates of the samples which were produced while binaural masking was presented were significantly slower than the control condition rates. The mean rate per second for the masking treatment was 4.76. This was .69 syllables per second slower than the comfortable pitch and intensity mean rate and .59 syllables per second slower than the comfortable pitch-controlled intensity treatment mean rate. These reductions in rate of the phonatory task are consistent with reported diminutions in the speed of conversational speech when masking noise was presented binaurally (20).

It can be inferred that either auditory feedback was important in synchronizing laryngeal motor behavior or the subjects' approach to the phonatory task was altered when masking was presented. The ear somehow acted to regulate the rapid laryngeal movements during the performance of vocal fold diadochokinesis. Lack of change in rate, periodicity, and pattern measurements after anesthetization disrupted laryngeal somesthetic feedback may have resulted from the method of anesthetization and/or

the extent to which the action of the somesthetic receptors was eliminated.

Changes in vocal intensity were noted in the diadochokinetic samples produced after the larynx was anesthetized (See Table XIX, page 104). Although the intensity measurements were numerically higher after anesthetization for all but one subject, a comparison of these differences did not approach the significance level utilized in this study. This observation is of particular interest because speech scientists have previously only studied the disruption of auditory feedback as a factor in altering vocal intensity. The present findings suggest that the relationship between vocal parameters and disruption of laryngeal somesthetic feedback should be examined.

C. VARIABLES AFFECTING VOCAL FOLD DIADOCHOKINESIS

Data collected in this study confirm the findings of Ptacek and Sander (42) that pitch and intensity are important variables to consider in studying phonatory abilities. Although periodicity measurements were not significantly changed by alterations in these variables, it was disclosed that subjects' rates and percentages of abducted syllables were affected by changes in pitch and intensity.

Analysis of the main treatment effects demonstrated

that pitch and interaction between pitch and intensity had significant effects on the rate measurements. A more detailed analysis was made of the rate measurements when intensity was varied at each pitch level and when pitch was altered as the intensity of phonation was kept relatively constant. Significant differences in rate were noted for the low pitched, comfortably pitched, and high pitched conditions when intensity was varied in each instance. Moreover, altering pitch produced significant differences in rates when vocal fold diadochokinesis was performed at comfortable and high intensity levels.

Inspection of the data disclosed that the highest rates of vocal fold diadochokinesis occurred when the task was performed at the persons' comfortable pitch and intensity level. The rates were noticeably slower as intensity was diminished at the comfortable pitch level, but only a slight reduction in rate, not statistically significant, was noted at this level with increased intensity of phonation.

Differences in rate were more evident when low pitches were used. Moreover, augmentation of intensity at low pitches resulted in reduced rates. Interestingly, the opposite trend was observed when the phonatory task was produced at high pitches. i.e., rates of highest intensity samples were higher.

The fact that the rates of vocal fold diadochokinesis were highest at the comfortable pitch and intensity levels indicated that optimum performance of the laryngeal musculature seemed to be present when no restrictions were placed upon the vocal mechanism. The lowering of rates as intensity levels were decreased and increased at this pitch level further verified this observation.

When considering the effect of pitch and intensity upon rates of vocal fold diadochokinesis, it would seem that maximum assessments would be obtained during clinical evaluations if subjects were asked to phonate at comfortable pitch and intensity levels. It cannot be stated with certainty, however, whether the persons participating in this study were performing the task at their optimum pitch level. The mean pitch observed for the comfortable pitch and intensity treatment was 242.35 cycles per second with a standard deviation of 38.50 cycles per second. Although the pitch of the subjects' conversational speech was not assessed, the mean pitch measurement appeared to be slightly higher than reported average pitches for women (30, 33, 47). However, the samples of vocal fold diadochokinesis were within the pitch range of 154.5-264.6 cycles per second found by evaluating the pitch utilized by women during conversational speaking (33). It seemed possible that the females participating in the present

investigation might not have been phonating at their most comfortable pitch level. Further investigation would be needed to demonstrate this fact.

The significant difference between the percentage of abducted syllables for the nine pitch and intensity treatments led to further exploration of the data. Pitch and intensity were found to be main effects influencing the percentage of abducted syllable measurements. However, interaction between the treatments was not evident from the analysis. The percentages of abducted syllables present when pitch of phonation was relatively stabilized and intensity varied and when intensity was maintained as pitch was varied were tested statistically. Only the low pitch-varied intensity and the high pitch-varied intensity conditions yielded significance. There seemed to be a parallelism between the low and high pitch samples. i.e., increases in intensity were accompanied by decreases in abducted syllables. While this trend was also seen in the comfortable pitch means, it was not as prominant as the others and was not statistically significant. The highest percentages of abducted syllables were observed when the intensity of the vocalizations was between 62 and 68 db (re: reference level calibrated to 80 db SPL) and when high pitches were used. It appeared that increases in intensity somehow restricted vocal fold abduction during production of

the syllable [hʌ].

Comparison of rate and percentage of abducted syllables during pitch and intensity conditions was possible in some cases. It was noticed that at low pitches rate was slower and the percentage of abducted syllables was also diminished. Furthermore, rate increases at high pitches were associated with decreases in the percentage of abducted syllables.

Although the differences between the phonation time measurements did not approach statistical significance, these data deserve further comment. The mean percentage of phonation time was largest when the subjects performed the task loudly in a low pitched voice. Moreover, the length of phonation time was longest for all of the low pitched samples. The duration of phonation appeared to be about equal for comfortable and high pitches at the highest intensity level, but high pitches generally seemed to result in the smallest proportions of phonation time at the other intensity levels.

The results of this investigation concluded that aging did not affect rate, periodicity, or pattern of vocal fold diadochokinesis. This is contrary to Ptacek and Maloney's (41) findings when the rate of a similar task was measured in young adult and geriatric populations. Table XXI enumerates the means and standard deviations of

TABLE XXI

SUMMARY OF THE MEANS AND STANDARD DEVIATIONS OF THE RATES (PER SECOND) OF VOCAL FOLD DIADOCHOKINESIS AS PERFORMED BY YOUNG ADULT AND SENESCENT FEMALES WHO PARTICIPATED (1) IN THE PRESENT INVESTIGATION AND (2) IN PTACEK AND MALONEY'S STUDY

GROUPS	NUMBER OF SUBJECTS	MEAN RATES	STANDARD DEVIATION
Young adult (1)	40	5.46	.57
Young adult (2)	31	5.30	.98
Senescent (1)	40	5.54	.75
Senescent (2)	29	3.90	1.28

rates as vocal fold diadochokinesis was performed by young adult women and by women in the late senescent period of life who participated in the present investigation and in Ptacek and Maloney's study (41). Although it is apparent that the rates produced by the senescent women who took part in the latter study were slower than the rates of the oldest females tested by the writer, statistical comparison of the data obtained in the two experiments was not made because of the influence of unknown experimental and subject variables. The rate differences might be a reflection of the recording and analytical procedures employed by the two investigators or of the use of rapid productions of the [ʌ] vowel rather than repetition of the glottal fricative-vowel syllable as the test of vocal fold diadochokinesis.

Interpretation of the data in Table XXI deserves further deliberation. Ptacek and Maloney (41) explained that faster rates might have been established for their geriatric group under ideal motivating conditions and with repeated trials. Their subjects reportedly had difficulty comprehending the task.

The present investigator attempted to eliminate the influence of inadequate trials by allowing each person to practice the task three times before tape recording three samples to be analyzed. Although the investigator did not design any special methods to increase motivation and

comprehension of the task, problems in these areas were not evident.

The fact that the senescent women participating in the present experiment were often tested in groups of three or four might have accounted for their apparent high motivation level. Furthermore, being able to observe the other women as they performed the task might have allowed the subjects to comprehend the instructions more easily.

Ptacek and Maloney's (41) sample might have accounted for their finding that aging women produced vocal fold diadochokinesis at a slower rate than young adult females. These investigators included persons who were confined to a home for the aged. It is conceivable, therefore, that the senescent women who produced higher rates in the present experiment might have been easier to motivate since they were more actively functioning in society. Moreover, it is possible that the measurements obtained in the present investigation might actually have been less influenced by aging because the individuals were healthy enough not to have to be confined to rest homes. If none of the above factors were responsible for the differences observed between the rates produced by the senescent groups, differences must have been due to some unknown sampling error. The findings relative to aging did indicate that in the future caution should be executed in selecting a

representative geriatric sample and in accepting conclusions based on hypotheses tested on such samples.

D. POSSIBLE SOURCES OF ERROR

Although the reliability coefficients cited in a previous chapter suggested that the results obtained in this experiment were highly consistent, the accuracy of the data could have been influenced by subject and experimental variables. The subjects who participated in the study were thought to represent a normal population. However, comparison of the rate of vocal fold diadochokinesis when performed by the oldest group of women and of the mean rate when another geriatric group (41) produced a similar phonatory task pointed to some unknown sampling error.

The examiner attempted to standardize her testing procedures. Each subject was instructed to clearly articulate the syllable designed for the test, yet the spectrographic analyses did not always indicate that the complete syllable was being uttered. It seemed possible, in one particular instance, that the auditory monitoring of the task by the investigator and several subjects was perhaps insufficient to acknowledge the absence of a well articulated syllable. These subjects were five nuns ranging from twenty to thirty-two years of age. Continuous

phonation was often evident when analyzing spectrograms of their performances. It was first theorized that the acoustics in the convent were poor, but analysis of spectrograms of ten older sisters' samples, recorded in the same room, revealed 100 per cent abduction in every case but one. Since the task is similar to the method of chanting prayers, it may be that the younger sisters followed this pattern during the experimental testing.

It was felt that a reasonable number of subjects were selected for the collection of the data. However, only ten persons participated in the anesthetization treatment. Therefore, the fact that rate, periodicity, and pattern of vocal fold diadochokinesis were not affected by topical anesthetization of the larynx must be accepted with caution. Significant data might have been collected if a larger number of subjects had taken part in this procedure. Additionally, even though subjects failed to react to glottic stimulation after anesthesia, it is not known whether the anesthetization was sufficient to disrupt all of the sensory receptors of the larynx.

When designing the procedures for the youngest group of women, the number of trials had to be limited because of fatigue factors and time limitations. Since the subjects were not retested, it cannot be established with certainty that the data reported actually represent maximum vocal

fold diadochokinetic ability. However, it was felt that the number of trials, fixed according to the results of a pilot study, should have produced a representative estimate of a person's maximum performance of the task. The twenty individuals who took part in the preliminary investigation produced their highest rates during the fourth and fifth trials. In the present study, three practice trials were required and measurements were taken from the next three trials, which according to the prior investigation would have been performed most rapidly. Moreover, the pilot study measurements of the variation of the individual trials from the mean of the trials indicated that the mean was representative of the subjects' maximum ability to perform the task. Based on these findings, the mean rate per second was selected as a measurement of each subject's vocal fold diadochokinetic ability.

The possibility of error resulting due to the small number of phonation time observations compared was considered by the investigator. The fact that only eight control samples of vocal fold diadochokinesis, performed at comfortable pitch and intensity levels, had 100 per cent abducted syllables necessitated limiting the number of observations of phonation time to be tested for significance. However, assumptions for using parametric statistics were met by randomly selecting the samples of the other

experimental conditions to be compared with the control. This method of handling the data should have minimized error.

The question relative to whether pattern data taken from one sample could be considered representative of a subject's ability was also contemplated by the investigator. Material costs and time restrictions were important in selecting this limited sample for analysis. The amount of measurement error arising from these limitations is unknown.

The methods of analyses were controlled as carefully as possible. However, spectrographic measurement error could have complicated the data. For example, although it was possible to begin making the graphic level tracings before any portion of the tape recorded sample was played, the first syllable had to be heard before the Sono-Graph could be started. Otherwise the investigator might have obtained a tracing less than 2.4 seconds in duration. Therefore, timing errors might have caused the spectrographic samples to differ slightly from the graphic level tracings of the task. Difficulty in distinguishing the exact initiations and terminations of phonation during analyses of the spectrograms also could have resulted in error, but Pearson rs cited in a previous chapter indicated that these assessments were highly reliable.

Furthermore, the validity coefficients of the pitch measurements might have been subject to error. Due to time limitations, the investigator neglected to recheck the frequency response characteristics of the Sono-Graph before submitting the thirty vocal fold diadochokinetic samples to spectrum analysis.

E. IMPLICATIONS FOR CLINICAL USE OF VOCAL FOLD DIADOCHOKINESIS

Certain factors have been noted in this study which add to the clinical usefulness of the task. For example, it was discovered that variations in pitch and intensity affected performances of the phonatory task. While it is not possible to infer that these findings can be applied to all patients whose voices are deviant in pitch and intensity characteristics, it seems logical to assume that persons with functional pitch and intensity problems might have difficulty performing vocal fold diadochokinesis. If so, their poor performance might be a reflection of their alterations in pitch and intensity.

Moreover, information discussed in this chapter suggested that an elderly person's deviant performance of the task would not necessarily be due to aging factors. Problems with vocal fold diadochokinesis would seem to point to the need for medical examination if a diagnosis

other than disordered speech had not already been made.

The above implications are important for the clinician to recognize, but the need to find a practical method of analyzing the task seems of primary concern. Vocal fold diadochokinesis cannot be used effectively in diagnosing phonatory problems until such a method has been found.

F. SUGGESTIONS FOR FUTURE RESEARCH

There seem to be several possible steps which might be taken to establish an adequate method of analyzing samples of vocal fold diadochokinesis. The first might be to determine when abduction of the vocal folds occurs during the performance of the task. Electromyography and cineradiology could be utilized to accomplish this goal. Secondly, if graphic level tracings and spectrograms could be made simultaneously with the above analyses, information could be obtained which should permit the clinician to be better able to discriminate the presence and the degree of vocal fold abduction by inspecting these representations of phonation. Cineradiographic techniques might also be used to determine whether repetition of [ʌ], /hə/, or [hʌ] is the best test of vocal fold diadochokinesis.

After a more adequate method of interpreting the data and the best test of vocal fold diadochokinesis have

been found, it would be desirable to establish norms for the phonatory task. With the normative data collected, investigation of the performance of clinical groups should be initiated.

Clinical observations have suggested that neurologically involved patients have difficulty producing syllables rapidly. It is not known whether this behavior is due to laryngeal musculature incoordinations or if it results from lack of adequate breath pressure. Future investigators might attempt to study these problems.

It might also be beneficial to begin longitudinal testing of the task as performed by persons with functional voice problems. This type of data could unfold additional information relating to the effect of pitch and intensity on the task.

The results of the investigation suggest that disruption of laryngeal somesthetic feedback does not produce changes in rate, periodicity, and pattern of vocal fold diadochokinesis. However, since the sample participating in this condition was rather small, it was felt that this procedure might be used with a larger population to ascertain whether significant differences would occur. Other methods of anesthetization might also be tried to see if they yield different results.

Secondary information concerning pitch levels

utilized during phonation was also obtained in this investigation. The mean fundamental frequency of the women's performance of the task at comfortable pitch levels was slightly higher than average pitch values reported by previous investigators (30, 33, 46, 47). Means and standard deviations of these values can be found in Appendix B.

Ptacek and Sander (42) also reported average frequencies that were higher than would be expected from previous reports. The authors (42) theorized that female adults employ higher pitches during non-speech activities than during conversational speaking. However, since neither the present investigator nor Ptacek and Sander measured the participants' pitch during conversational speech, it is not known whether these particular subjects utilized higher pitches during the experimental procedures. It would seem advantageous to compare a subject's average pitch during speaking with his pitch during phonatory activities such as vocal fold diadochokinesis. A better understanding of the nature of phonation could be gained from such an investigation.

CHAPTER VI

SUMMARY AND CONCLUSIONS

A. INTRODUCTION

Speech pathologists have recently begun to study tasks which can be used in the diagnosis of phonatory problems. One task which has been recommended for testing vocal fold abduction and adduction is the rapid repetition of either a neutral vowel or a syllable containing a vowel and the glottal fricative. This task is referred to as vocal fold diadochokinesis.

The few references which have dealt specifically with this phonatory ability have reported rates of performance (6, 41, 44). However, clinical observations have indicated that other measurements should be made of vocal fold diadochokinetic samples. i.e., pattern and periodicity. Furthermore, research relative to the role of sensory feedback in the performance of phonatory tasks has suggested that assessments of vocal fold diadochokinesis might be dependent upon a number of factors (19, 31, 32, 41, 42). It may be that synchronization of the vocal mechanism during performances of the phonatory task is dependent upon sensory feedback systems. Furthermore, modifications in a person's phonation of the task may occur due to variations

in pitch and intensity. It was felt that aging might also be a factor in vocal fold diadochokinetic ability. Geriatric women's rates of performing the task were previously noted to be significantly slower than those of young adult females (41), but measurements of periodicity and pattern of the aging women's diadochokinetic samples were not made. Inferences regarding the relationship between deviant diadochokinetic abilities and phonatory problems could not be made until more information was available regarding the nature of the phonatory task and the effect of the above noted variables upon its performance.

B. STATEMENT OF THE PROBLEM

The present investigation was designed to study the nature of vocal fold diadochokinesis and the effects of pitch, intensity, and aging upon performances of the phonatory task.

C. SUBJECTS AND PROCEDURES

One hundred and thirty individuals, who evidenced normal health, hearing acuity, and vocal quality, were selected to participate in the study. The rapid repetition of the syllable [hʌ] was used as a measure of vocal fold diadochokinesis. Tape recordings were made of the subjects' productions of the phonatory task. Vocal fold diadocho-

kinesis produced by one hundred and twenty women, who were grouped according to three age classifications, was analyzed to determine the effects of aging upon the task. Forty of the youngest women rapidly repeated the syllable [hʌ] in compliance with specified conditions designed to evaluate disruption of the auditory feedback mechanism and the importance of pitch and intensity changes. Ten individuals underwent topical anesthetization of the larynx so that the influence of somesthetic feedback on rapid vocal fold abduction-adduction could be examined.

Differences in rate, periodicity, and pattern of vocal fold diadochokinesis due to the experimental treatments were calculated and analyzed for significance by several analysis of variance designs, by t-tests of paired observations, and by a Wilcoxon matched-pairs signed-ranks test.

D. RESULTS

1. Nature of Vocal Fold Diadochokinesis

a. Effect of disruption of auditory feedback upon vocal fold diadochokinesis. The first experimental hypothesis tested was that there are no significant differences in the rate of vocal fold diadochokinesis (1) when the task is performed at a comfortable pitch and intensity level, and (2) when it is performed at a

comfortable pitch level, with intensity controlled and binaural masking disrupting auditory feedback. Significantly slower rates resulted when the subjects were presented with auditory masking to cause disruption of auditory feedback. These differences in rate would only have occurred by chance one time out of one hundred. Therefore, the hypothesis relative to rate was rejected.

The second experimental hypothesis was that there are no significant differences in the periodicity of vocal fold diadochokinesis (1) when the task is performed at a comfortable pitch and intensity level, and (2) when it is performed at a comfortable pitch level, with intensity controlled and binaural masking disrupting auditory feedback. Comparison of the periodicity measurements did not produce significant results. Therefore, the null hypothesis referable to periodicity and the above experimental treatments was accepted.

The third experimental hypothesis tested was that there are no significant differences in the pattern of vocal fold diadochokinesis (1) when the task is performed at a comfortable pitch and intensity level, and (2) when it is performed at a comfortable pitch level, with intensity controlled and binaural masking disrupting auditory feedback. Significant differences in the pattern of the phonatory task were not present when auditory feedback was

disrupted. On the basis of this experimental finding, the third hypothesis was accepted.

b. Effect of disrupting laryngeal somesthetic feedback upon vocal fold diadochokinesis. The fourth experimental hypothesis was that there are no significant differences in the rate of vocal fold diadochokinesis before and after topical anesthetization of the larynx. Based on the findings summarized in Chapter IV this hypothesis could not be rejected.

The fifth experimental hypothesis stated that there are no significant differences in the periodicity of vocal fold diadochokinesis before and after topical anesthetization of the larynx. Comparison of the periodicity measurements before and after the experimental treatment did not yield significant results. Therefore, the fifth hypothesis was accepted.

The sixth experimental hypothesis tested was that there are no significant differences in the pattern of vocal fold diadochokinesis before and after topical anesthetization of the larynx. The findings of the present investigation did not demonstrate that this hypothesis could be rejected.

2. Effect of Varying Pitch and Intensity upon Vocal Fold Diadochokinesis

The seventh experimental hypothesis stated that there are no significant differences in the rate of vocal fold diadochokinesis when pitch and intensity levels are varied. The F ratio comparing the nine pitch and intensity treatment means was significant at the .01 level of confidence. Moreover, analysis revealed that the pitch treatment effect caused significant differences in rate during performances of the task. Interaction between the pitch and intensity treatments was also significant in affecting the rates of vocal fold diadochokinesis. It was further established that rate was significantly different when intensity was varied as vocal fold diadochokinesis was performed at relatively stable low, comfortable, and high pitch levels. In addition, altering pitch when intensity was maintained at comfortable and high levels produced significant changes in rate. Significant differences found between pairs of rate means further substantiated the premise that pitch and intensity were important variables to consider when measuring rate of the phonatory task. On the basis of these experimental findings, the hypothesis can be rejected with confidence.

The eighth experimental hypothesis was that there are no significant differences in the periodicity of vocal fold diadochokinesis when pitch and intensity levels are varied. Comparison of the periodicity data relative to

pitch and intensity changes was not statistically significant. Therefore, it was not possible to reject the eighth null hypothesis.

The ninth experimental hypothesis stated that there are no significant differences in the pattern of vocal fold diadochokinesis when pitch and intensity levels are varied. The evaluation of the differences in the percentage of abducted syllables for the nine pitch and intensity treatment conditions produced an F ratio which was significant at the .01 level of confidence. It was also found that pitch was a significant factor in determining the percentage of abducted syllables during performance of the phonatory task. In addition, the intensity treatment affected the measurements of abducted syllables significantly. However, significant interaction between pitch and intensity treatments was not evident. Differences in the percentages of abducted syllables were found to be significant when subjects performed the task in a low pitched voice while varying intensity and in a high pitched voice across three levels of vocal intensity. Comparison of pairs of mean percentages of abducted syllables reached statistical significance in four instances.

The percentage of phonation time was not statistically significant due to variations in pitch and intensity. Since the pattern of vocal fold diadochokinesis refers to

measurements of the percentage of abducted syllables and of the percentage of phonation time, the only part of the pattern hypothesis which can be rejected with confidence is the former portion referable to the percentage of abducted syllables.

3. Effect of Aging upon Vocal Fold Diadochokinesis

The tenth hypothesis tested was that there are no significant differences in the rate of vocal fold diadochokinesis when the task is performed by young adult women, by mature women, and by women in the late senescent period of life. The results of analyzing the rate data referable to aging were not statistically significant. Therefore, the null hypothesis was accepted.

The eleventh hypothesis was that there are no significant differences in the periodicity of vocal fold diadochokinesis when the task is performed by young adult women, by mature women, and by women in the late senescent period of life. The F ratio resulting from a simple randomized analysis of variance of the periodicity data was not found to be significant. On the basis of this finding, the hypothesis could not be rejected.

The twelfth experimental hypothesis stated that there are no significant differences in the pattern of vocal fold diadochokinesis when the task is performed by

young adult women, by mature women, and by women in the late senescent period of life. The effect of aging on the percentage of abducted syllables and on the percentages of phonation time during vocal fold diadochokinesis was evaluated to test the above hypothesis. The analyses failed to yield significant values. Therefore, this hypothesis was accepted.

E. DISCUSSION

It was inferred from the results of the investigation that the physiological process which is responsible for coordinating rapid, laryngeal, abduction-adduction movement is somehow dependent upon information obtained from the auditory mechanism or that a person's approach to the vocal fold diadochokinetic task is altered when auditory feedback is disrupted. The fact that subjects performed vocal fold diadochokinesis significantly slower when auditory feedback was disrupted suggested that sensory mechanisms of the ear are important determinants in synchronizing laryngeal movements. This finding is consistent with previous reports of reductions in rates of speaking under masking conditions (20), and possibly explains some of the difficulty the deaf have in coordinating their vocalizations.

Although the present investigation attempted to

evaluate the role of non-auditory or somesthetic feedback systems in coordinating the laryngeal motor movements involved in vocal fold diadochokinesis, the findings did not indicate that laryngeal behavior was dependent upon these mechanisms. The fact that disruption of somesthetic feedback did not alter diadochokinetic measurements obtained in this study may have resulted from the small sample utilized in this procedure or the method of anesthetization. The anesthesia was the type most frequently employed during laryngeal examinations (10), but it may not have been adequate to eliminate all laryngeal sensory feedback. It is speculated that significant differences in vocal fold diadochokinetic assessments might be found if a larger sample and different anesthetization procedures were employed. Therefore, the present findings should not be considered conclusive and should be accepted with caution.

The investigator consistently observed increases in vocal intensity of the samples of vocal fold diadochokinesis produced after anesthesia disrupted somesthetic feedback. Statistical evaluation of the intensity data did not yield significant levels required for this study. However, the phenomenon is of interest because increases in vocal intensity are usually only thought of as being associated with disruption of auditory feedback. Since

the relationship between disruption of laryngeal somesthetic feedback and vocal parameters has not been studied, this finding could introduce a new area of research to the speech scientist.

The findings from this study indicated that there is a relationship between changes in pitch and intensity and rates of vocal fold diadochokinesis. Rates were highest when subjects performed the phonatory task at comfortable pitch and intensity levels. It appeared that the task should be performed in this manner if maximum rates are to be obtained during clinical evaluations. Moreover, it can be inferred that the laryngeal mechanism functioned more efficiently when the individual was able to maintain a more nearly habitual manner of vocalization.

It was pointed out previously that pitch measurements for the comfortable pitch conditions were higher than those previously reported for conversational speech (30, 33 46, 47). The significance of this phenomenon was considered beyond the scope of this study. It was noted, however, that other investigators also have reported high pitch assessments when subjects performed non-speech activities (42).

Differences in rate were most evident during low pitched productions of the diadochokinetic syllable. As intensity increased at this pitch level, rates became slower. The opposite trend occurred when high pitches were

employed. Rates were increased as intensity was augmented at high pitches. These findings have implications for the examination of patients with deviant pitch and intensity characteristics. It seems probable that these patients might exhibit poor performances of vocal fold diadochokinesis since maximum rates were observed to occur at comfortable pitch and intensity levels. Longitudinal studies of diadochokinetic ability as patients with pitch and intensity disorders undergo voice therapy could provide the data to demonstrate the acceptability of such an assumption.

Percentages of abducted syllables were also found to be affected by the pitch and intensity of phonation. Decreases in the percentages occurred at high and low pitches when intensity was increased. It would appear that increased intensity of phonation somehow restricts the vocal mechanism when subjects use unnatural pitch levels. Although the data referable to the percentage of phonation time at various pitch and intensity levels did not reach statistical significance, it was noticed that the largest periods of phonation time were recorded when subjects performed the task in a low pitched voice.

The present study failed to indicate that aging affects a woman's vocal fold diadochokinetic ability. This finding is contrary to the result of a former

investigation (41) in which women in the late senescent period of life were found to produce vocal fold diadochokinesis at significantly slower rates than young adult females. It was suggested that the differences in the results of the two studies could be explained on the basis of choice of subjects and measurement techniques. The discrepency between these results emphasized the importance of being cautious in selecting subjects and in accepting conclusions relative to geriatric populations. The present findings indicate that an older woman's deviant performance of vocal fold diadochokinesis would not necessarily be a sign of aging, but rather a possible indication of the need for a medical examination.

F. CONCLUSIONS

From the results of the present investigation the following conclusions were drawn:

1. Vocal fold diadochokinetic rate is decreased in the presence of auditory masking sufficient to disrupt auditory feedback. It would appear that either auditory feedback is influential in synchronizing laryngeal motor behavior or that a subject alters his approach to the phonatory task when masking disrupts the auditory feedback process.

2. Periodicity and pattern of vocal fold diadocho-

kinesis appear not to be affected by disruption of auditory feedback.

3. The finding that disruption of somesthetic feedback did not produce differences in rate, periodicity, and pattern of vocal fold diadochokinesis should be accepted with caution until additional research can be carried out. It is felt that using a larger sample and employing other methods of laryngeal anesthetization might yield different results.

4. Vocal fold diadochokinetic rate and percentage of abducted syllables are altered by certain changes in the pitch and intensity of phonation. Of clinical importance is the observation that maximum rate of vocal fold diadochokinesis is obtained when persons perform the task at their comfortable pitch and intensity levels.

5. Vocal fold diadochokinetic periodicity and percentage of phonation time do not appear to be affected by changes in pitch and intensity.

6. Rate, periodicity, and pattern of vocal fold diadochokinesis are not affected by aging.

The present investigation was undertaken from a rather broad viewpoint. It was suggested that future studies be planned to explore more extensively the specific questions that the present research has raised. For example, there is a need to establish a practical method of

analyzing the task in the clinic. Furthermore, investigation to determine the best test of vocal fold diadochokinesis is necessary. Norms should be established for the task, and finally, the study of clinical populations should be initiated. A more comprehensive understanding of the phonatory task could be gained after completion of this research.

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APPENDIX A

TABLE XXII

RATES (PER SECOND) WHEN VOCAL FOLD DIADOCHOKINESIS WAS PRODUCED BY FORTY YOUNG ADULT WOMEN USING (1) A COMFORTABLE PITCH AND INTENSITY LEVEL, (2) A COMFORTABLE PITCH LEVEL, CONTROLLING INTENSITY WHILE AUDITORY MASKING WAS PRESENTED BINAURALLY, AND (3) A COMFORTABLE PITCH WHILE CONTROLLING INTENSITY TO EVALUATE THE EFFECT OF DISRUPTING AUDITORY FEEDBACK

SUBJECTS	TREATMENTS (1)	(2)	(3)
1	5.44	3.89	4.56
2	5	4.22	4.22
3	4.44	3.22	3.56
4	6.11	4.44	6
5	6.11	6.11	6.67
6	5.89	3.56	3.78
7	5.22	6	6.33
8	4.44	3.44	3
9	6.22	5.44	6
10	5.44	4.44	5.11
11	4.89	4.67	5.33
12	5.89	4.44	6.22
13	6.22	5.22	6.22
14	4.78	4.22	5.22
15	5.67	5.11	5.44
16	5	3.56	4.89
17	4	4.67	4.56
18	5.89	6.22	5.89
19	5.78	5.22	6.11
20	6	4.33	6.56
21	5.22	5.44	4.78
22	5.56	4.33	5.11
23	4.56	4.33	4.33
24	5	3.67	4.78
25	5.22	3.22	5.33
26	5.56	4.44	5.33
27	5	6.11	6.22

TABLE XXII (continued)

SUBJECTS	TREATMENTS (1)	(2)	(3)
28	5.44	5.67	5
29	5.44	3.89	5.78
30	5.67	5	5.11
31	5.33	1.78	4.89
32	5.44	6	6.11
33	5.44	5.22	5.56
34	5.33	5.56	4.89
35	5.56	5	5.89
36	6.56	5.89	6
37	5.56	5.22	5.78
38	6.22	6.44	6.56
39	6.33	5.44	6.22
40	5.33	5.56	4.67
Mean	5.45	4.77	5.35
Standard Deviation	.57	1.01	.86

TABLE XXIII

PERIODICITY OF VOCAL FOLD DIADOCHOKINESIS WHEN PRODUCED BY FORTY YOUNG ADULT WOMEN USING (1) A COMFORTABLE PITCH AND INTENSITY LEVEL, (2) A COMFORTABLE PITCH LEVEL, CONTROLLING INTENSITY WHILE AUDITORY MASKING WAS PRESENTED BINAURALLY, AND (3) A COMFORTABLE PITCH WHILE CONTROLLING INTENSITY TO EVALUATE THE EFFECT OF DISRUPTING AUDITORY FEEDBACK

SUBJECTS	TREATMENTS		
	(1)	(2)	(3)
1	2	2	2
2	3	1	1
3	1	5	1
4	2	1	0
5	1	1	1
6	2	3	2
7	3	2	4
8	2	1	2
9	1	4	2
10	2	2	1
11	1	1	1
12	2	3	1
13	1	2	1
14	3	3	2
15	1	2	2
16	2	3	2
17	2	1	2
18	2	2	1
19	1	1	2
20	2	1	1
21	2	1	2
22	1	1	2
23	3	2	2
24	2	2	1
25	1	1	1
26	1	1	1
27	3	1	1
28	1	1	0

TABLE XXIII (continued)

SUBJECTS	TREATMENTS (1)	(2)	(3)
29	2	2	2
30	1	0	1
31	3	2	1
32	1	2	3
33	1	1	1
34	2	2	2
35	1	2	1
36	2	2	3
37	1	3	1
38	4	1	1
39	1	2	2
40	1	1	1
Mean	1.75	1.78	1.50
Standard Deviation	.81	.97	.78

TABLE XXIV

PERCENTAGE OF ABDUCTED SYLLABLES WHEN VOCAL FOLD DIADOCHOKINESIS WAS PRODUCED BY FORTY YOUNG ADULT SUBJECTS USING (1) A COMFORTABLE PITCH AND INTENSITY LEVEL AND (2) A COMFORTABLE PITCH LEVEL, CONTROLLING INTENSITY WHILE AUDITORY MASKING WAS PRESENTED BINAURALLY TO EVALUATE THE EFFECT OF DISRUPTING AUDITORY FEEDBACK

SUBJECTS	TREATMENTS (1)	(2)
1	90	87.50
2	100	100
3	100	50
4	91.67	100
5	61.54	100
6	25	83.33
7	40	100
8	83.33	100
9	92.31	70
10	63.64	28.57
11	100	100
12	53.85	66.67
13	78.57	100
14	87.50	37.50
15	54.55	81.82
16	91.67	75
17	87.50	100
18	100	100
19	58.33	100
20	58.33	100
21	100	100
22	92.31	100
23	66.67	87.50
24	80	75
25	100	90.91
26	72.73	88.89
27	90	84.62
28	81.82	81.82
29	88.89	88.89

TABLE XXIV (continued)

SUBJECTS	TREATMENTS (1)	(2)
30	91.67	90
31	33.33	100
32	0	64.29
33	45.45	40
34	100	63.64
35	100	100
36	76.92	54.55
37	91.67	75
38	83.33	83.33
39	92.31	25
40	45.45	100
Mean	76.66	81.85
Standard Deviation	24.49	21.66

TABLE XXV

PERCENTAGE OF PHONATION TIME WHEN VOCAL FOLD DIADOCHOKINESIS WAS PRODUCED BY (1) EIGHT YOUNG ADULT WOMEN USING A COMFORTABLE PITCH AND INTENSITY LEVEL, AND (2) EIGHT YOUNG ADULT WOMEN USING A COMFORTABLE PITCH LEVEL, BUT CONTROLLING INTENSITY WHILE AUDITORY MASKING WAS PRESENTED TO DISRUPT AUDITORY FEEDBACK

SUBJECTS	TREATMENTS (1)	(2)
1	53.08	40.58
2	46.10	56.03
3	59.43	71.02
4	40.57	59.22
5	68.85	41.75
6	46.04	40.09
7	54.08	51.16
8	50.36	70.07
Mean	52.31	53.74
Standard Deviation	8.84	12.60

TABLE XXVI

RATES (PER SECOND) OF VOCAL FOLD DIADOCHOKINESIS WHEN TEN SUBJECTS PRODUCED THE TASK AT A COMFORTABLE PITCH AND INTENSITY LEVEL BEFORE AND AFTER ANESTHETIZATION DISRUPTED LARYNGEAL SOMESTHETIC FEEDBACK

SUBJECT	BEFORE ANESTHESIA	AFTER ANESTHESIA
1	3.33	3
2	4.77	4.33
3	2	2.22
4	3.44	4.33
5	4.77	4.66
6	4.33	3.77
7	4	3.55
8	4.11	4.66
9	4.77	4.44
10	4.33	4.44
Mean	3.98	3.94
Standard Deviation	.86	.81

TABLE XXVII

PERIODICITY OF VOCAL FOLD DIADOCHOKINESIS WHEN TEN SUBJECTS PRODUCED THE TASK AT A COMFORTABLE PITCH AND INTENSITY LEVEL BEFORE AND AFTER ANESTHETIZATION DISRUPTED LARYNGEAL SOMESTHETIC FEEDBACK

SUBJECT	BEFORE ANESTHESIA	AFTER ANESTHESIA
1	1	0
2	1	1
3	2	1
4	1	2
5	1	1
6	2	1
7	0	1
8	2	2
9	1	1
10	2	1
Mean	1.30	1.10
Standard Deviation	.68	.56

TABLE XXVIII

PERCENTAGE OF ABDUCTED SYLLABLES WHEN TEN SUBJECTS PRODUCED VOCAL FOLD DIADOCHOKINESIS AT A COMFORTABLE PITCH AND INTENSITY LEVEL BEFORE AND AFTER ANESTHETIZATION DISRUPTED LARYNGEAL SOMESTHETIC FEEDBACK

SUBJECT	BEFORE ANESTHESIA	AFTER ANESTHESIA
1	100	100
2	100	100
3	100	100
4	100	100
5	80	75
6	100	87.50
7	100	57.14
8	100	100
9	90	100
10	100	100
Mean	97	91.96
Standard Deviation	6.75	14.80

TABLE XXIX

SUMMARY OF THE MEAN PERCENTAGE OF PHONATION TIME WHEN SEVEN SUBJECTS PRODUCED VOCAL FOLD DIADOCHOKINESIS BEFORE AND AFTER TOPICAL ANESTHETIZATION WAS ADMINISTERED TO DISRUPT LARYNGEAL SOMESTHETIC FEEDBACK

SUBJECTS	BEFORE ANESTHESIA	AFTER ANESTHESIA
1	54.99	44.60
2	47.68	43.95
3	57.32	64.08
4	50.48	53.84
5	55.04	44.66
6	68.94	45.78
7	69.32	54.04
Mean	57.68	50.14
Standard Deviation	8.46	7.54

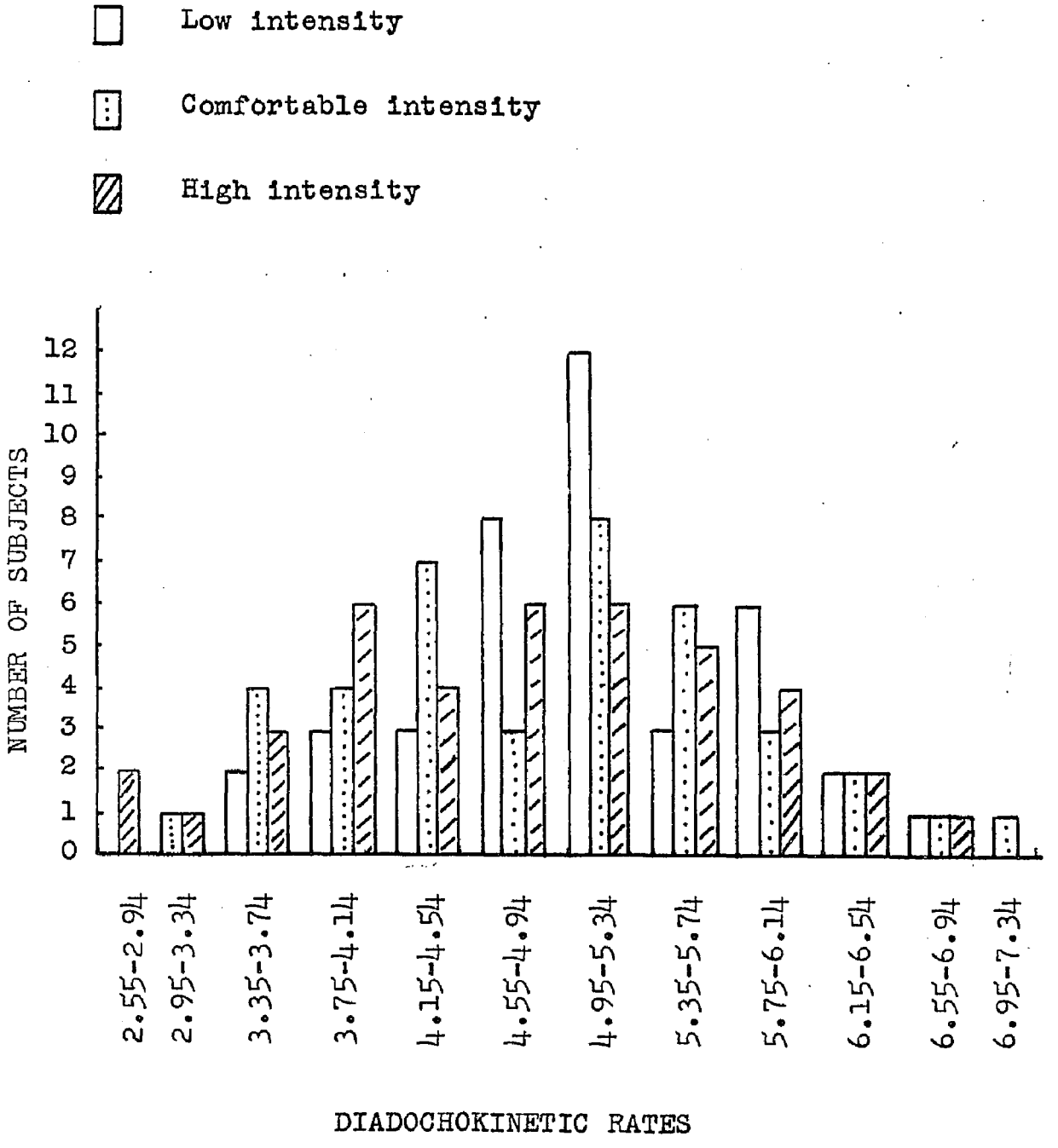


Figure 21. Rates (per second) of vocal fold diadochokinesis as performed in a low pitched voice across three levels of vocal intensity by forty young adult females.

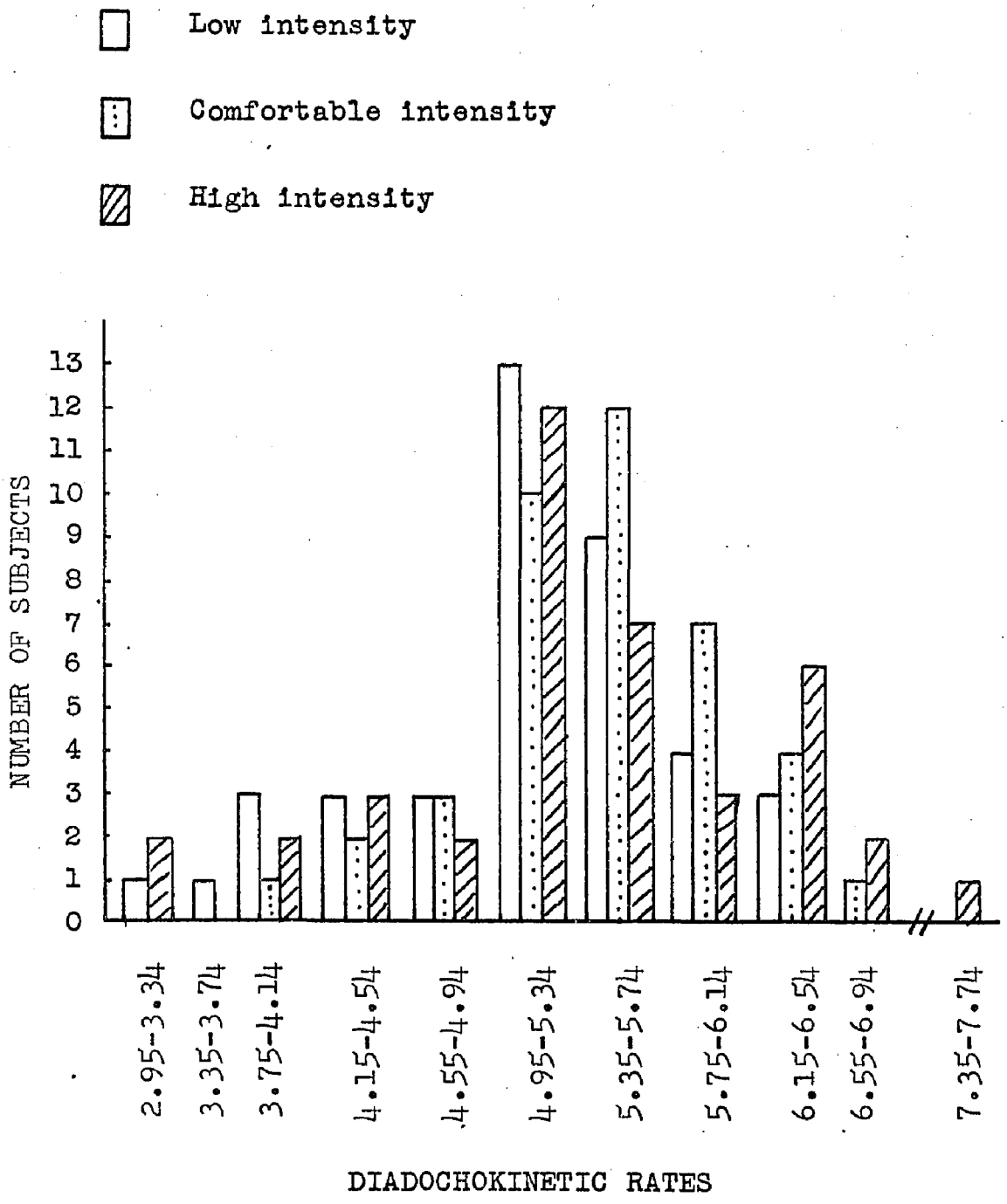


Figure 22. Rates (per second) of vocal fold diadochokinesis as performed in a comfortably pitched voice across three levels of vocal intensity by forty young adult females.

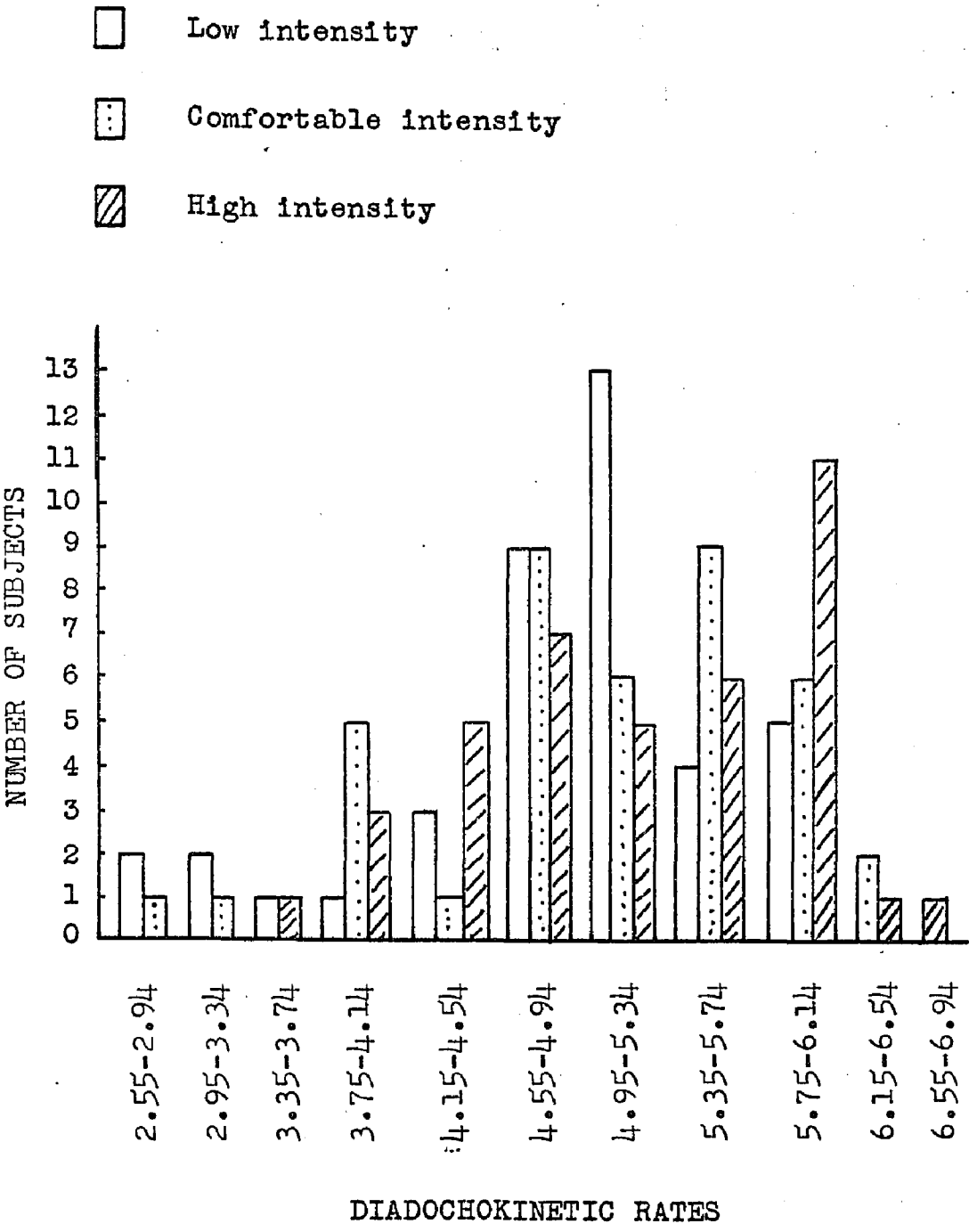


Figure 23. Rates (per second) of vocal fold diadochokinesis as performed in a high pitched voice across three levels of vocal intensity by forty young adult females.

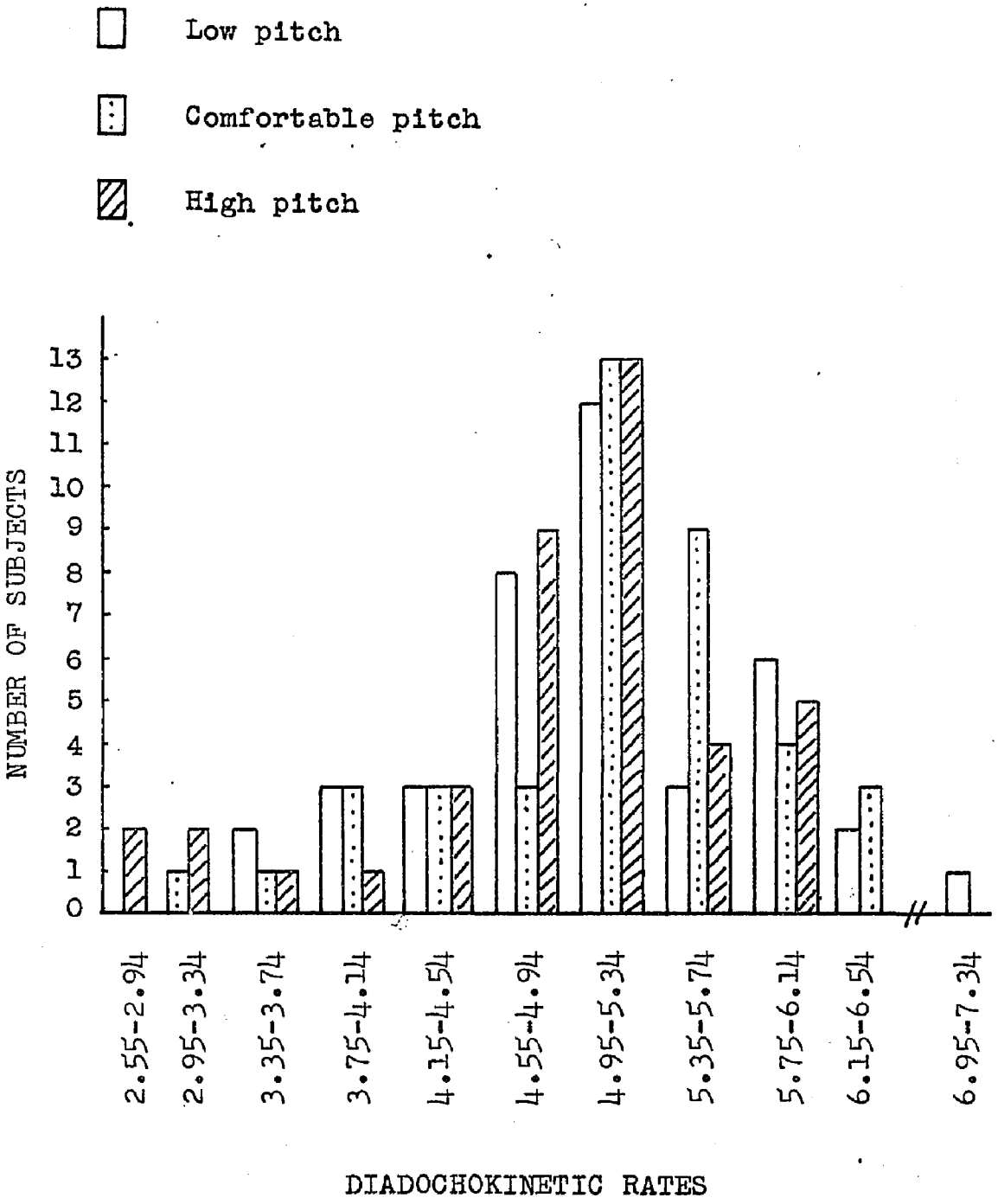


Figure 24. Rates (per second) of vocal fold diadochokinesis as performed at a low intensity level across three levels of vocal pitch by forty young adult females.

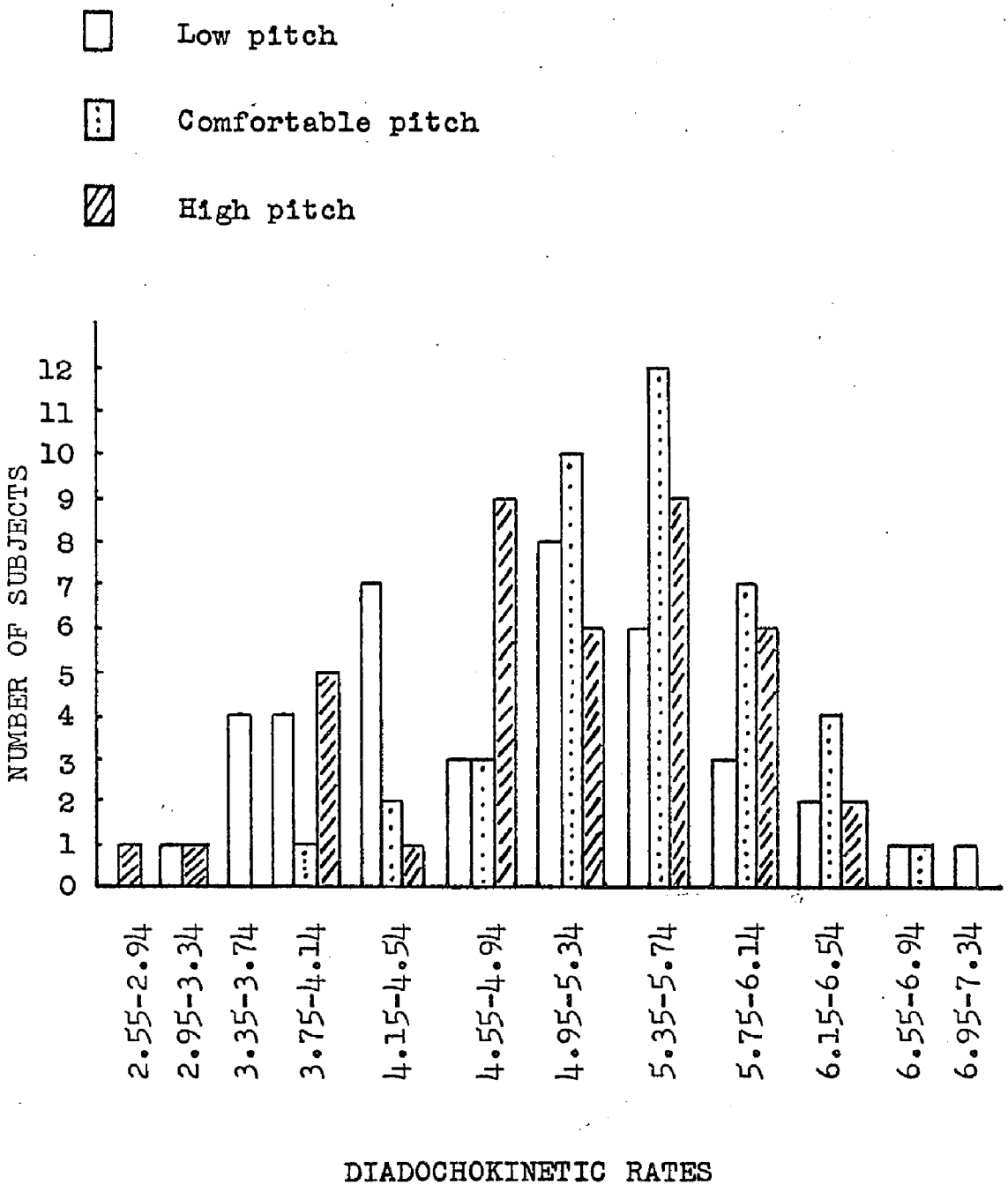


Figure 25. Rates (per second) of vocal fold diadochokinesis as performed at a comfortable intensity level across three levels of vocal pitch by forty young adult females.

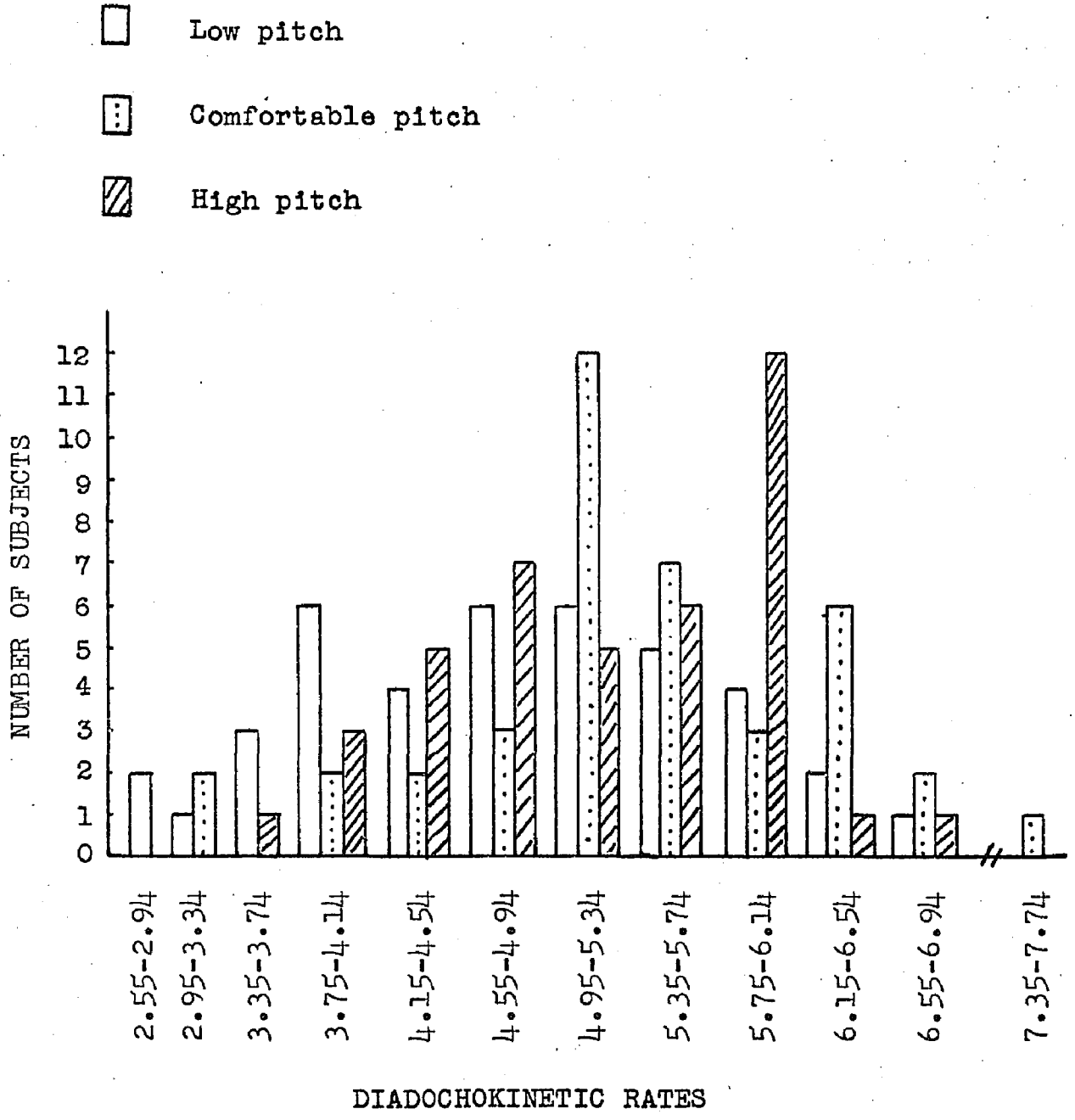


Figure 26. Rates (per second) of vocal fold diadochokinesis as performed at a high intensity level across three levels of vocal pitch by forty young adult females.

TABLE XXX

RATES (PER SECOND) WHEN VOCAL FOLD DIADOCHOKINESIS WAS PERFORMED BY FORTY YOUNG ADULT SUBJECTS AT (1) LOW PITCH-LOW INTENSITY, (2) LOW PITCH-COMFORTABLE INTENSITY, (3) LOW PITCH-HIGH INTENSITY, (4) COMFORTABLE PITCH-LOW INTENSITY, (5) COMFORTABLE PITCH-COMFORTABLE INTENSITY, (6) COMFORTABLE PITCH-HIGH INTENSITY, (7) HIGH PITCH-LOW INTENSITY, (8) HIGH PITCH-COMFORTABLE INTENSITY, AND (9) HIGH PITCH-HIGH INTENSITY LEVELS TO EVALUATE THE EFFECT OF VARIATIONS IN PITCH AND INTENSITY

SUBJECTS	TREATMENTS								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	5.22	5	5.44	5.33	5.44	5.33	5.33	5.33	5.22
2	5.11	5.44	5.11	5.44	5	5.67	5.33	4.11	4.44
3	5	3.44	4.11	4.78	4.44	4.67	3.33	3.33	3.44
4	4.89	5.67	5.33	5.56	6.11	5.67	5.78	5.89	5.89
5	6.22	6.67	6.33	6.22	6.11	6.44	5.78	6.33	6
6	3.89	3.67	3.56	4.89	5.89	3.89	3.11	3.78	4.78
7	6.56	5.89	6	5.56	5.22	6.44	5	5.78	5.56
8	4.56	3.89	3.33	3.22	4.44	3.78	5.78	5	4.67
9	6.22	6.33	6.89	5.22	6.22	7.67	5.56	5.67	5.89
10	5.22	5	4.89	5.44	5.44	5.22	5.22	5.44	5.22
11	4.78	5.67	5.78	5.78	4.89	5.33	4.89	5.44	5.67
12	5.33	5.11	5.22	3.89	5.89	5.56	4.78	4.89	5
13	5.67	5.67	5	5.44	6.22	6	5.44	5.11	5.78
14	4	4.44	4	5	4.78	5	4.89	5.11	4.44
15	3.44	5.44	5.89	4.11	5.67	5.89	4.78	5.11	5
16	5	4.78	4.44	5.11	5	5.11	4.67	4.78	4.56
17	4.22	3.89	4.22	4.44	4	4.22	4.67	4.89	4.89
18	5.78	5.89	5.44	5.11	5.89	5.89	4.33	4.89	5.78

TABLE XXX (continued)

SUBJECTS	TREATMENTS								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
19	5.89	5.78	5.44	5.89	5.78	6.33	5.22	5.78	5.89
20	5.78	5.33	5	6.33	6	6.33	5.33	5.22	6.11
21	4.33	3.67	2.78	4.78	5.22	5.67	5.22	4.11	4.33
22	4.56	4.44	4.56	5.44	5.56	5.44	5	4.67	4.33
23	3.56	3.33	4.56	3.44	4.56	3.22	3.44	2.89	3.89
24	4.22	3.78	4.11	4.44	5	4.56	4.22	4.44	4.56
25	4	4.33	3.44	4.22	5.22	4.22	2.89	3.78	3.89
26	5	4.67	4.44	5.33	5.56	5.22	4.67	4.56	4.78
27	6.11	4.44	4	5.22	5	5.22	5.22	5.89	6
28	4.89	4	3.89	5.33	5.44	5.56	4.78	4.56	4.78
29	4.67	4.22	3.44	5.33	5.44	4.44	4.11	4.89	4.44
30	4.89	4.89	4.56	5	5.67	5.22	4.67	4.67	5.22
31	5.11	3.67	2.78	5.22	5.33	3.33	2.67	4.11	4
32	5.67	5.44	5.33	6.11	5.44	5.33	5	5.44	6.33
33	5.78	5	4.89	5.56	5.44	5.56	5.22	5.67	5.78
34	5.11	4.33	4.11	5.56	5.33	5.33	4.33	5.78	5.56
35	5	5	4.78	5.78	5.56	5.33	5.67	5.56	5.67
36	5.89	6.44	5.56	3.78	6.56	6.44	5.67	5.44	5.67
37	5.33	5.22	5.67	5.11	5.56	6.33	5.78	5.67	5.89
38	5.67	5.33	5.78	5.56	6.22	6.89	5.78	6.22	6.67
39	5.33	7	6.33	6.33	6.33	6.67	5.33	5.89	6
40	4.78	4.22	4.44	5.11	5.33	5.33	5.22	5.44	5.44
Mean	5.07	4.91	4.77	5.14	5.46	5.39	4.85	5.04	5.19
Standard Deviation	.75	.93	.97	.73	.57	.95	.81	.78	.77

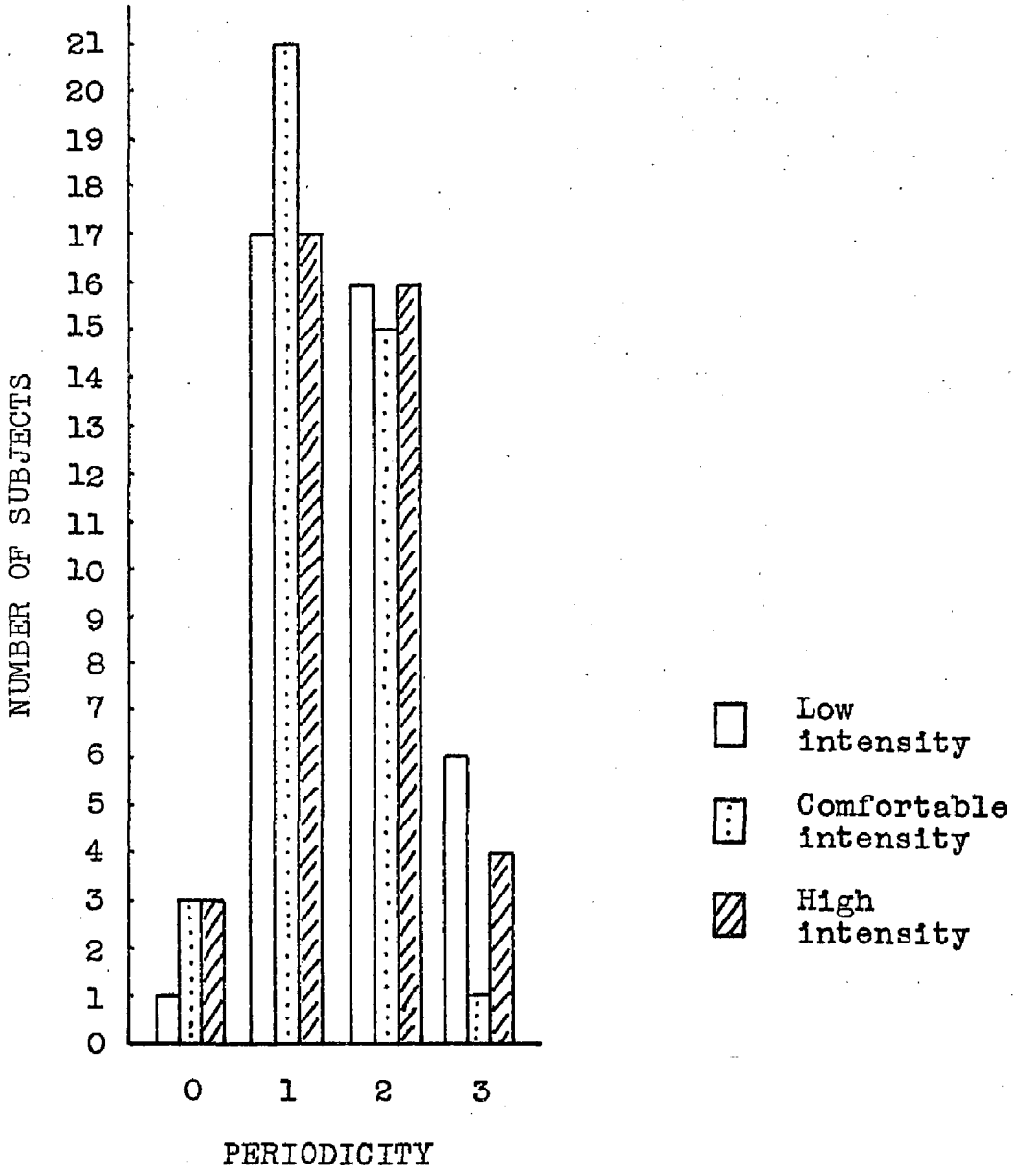


Figure 27. Periodicity values when forty young adult subjects produced vocal fold diadochokinesis in a low pitched voice across three levels of vocal intensity.

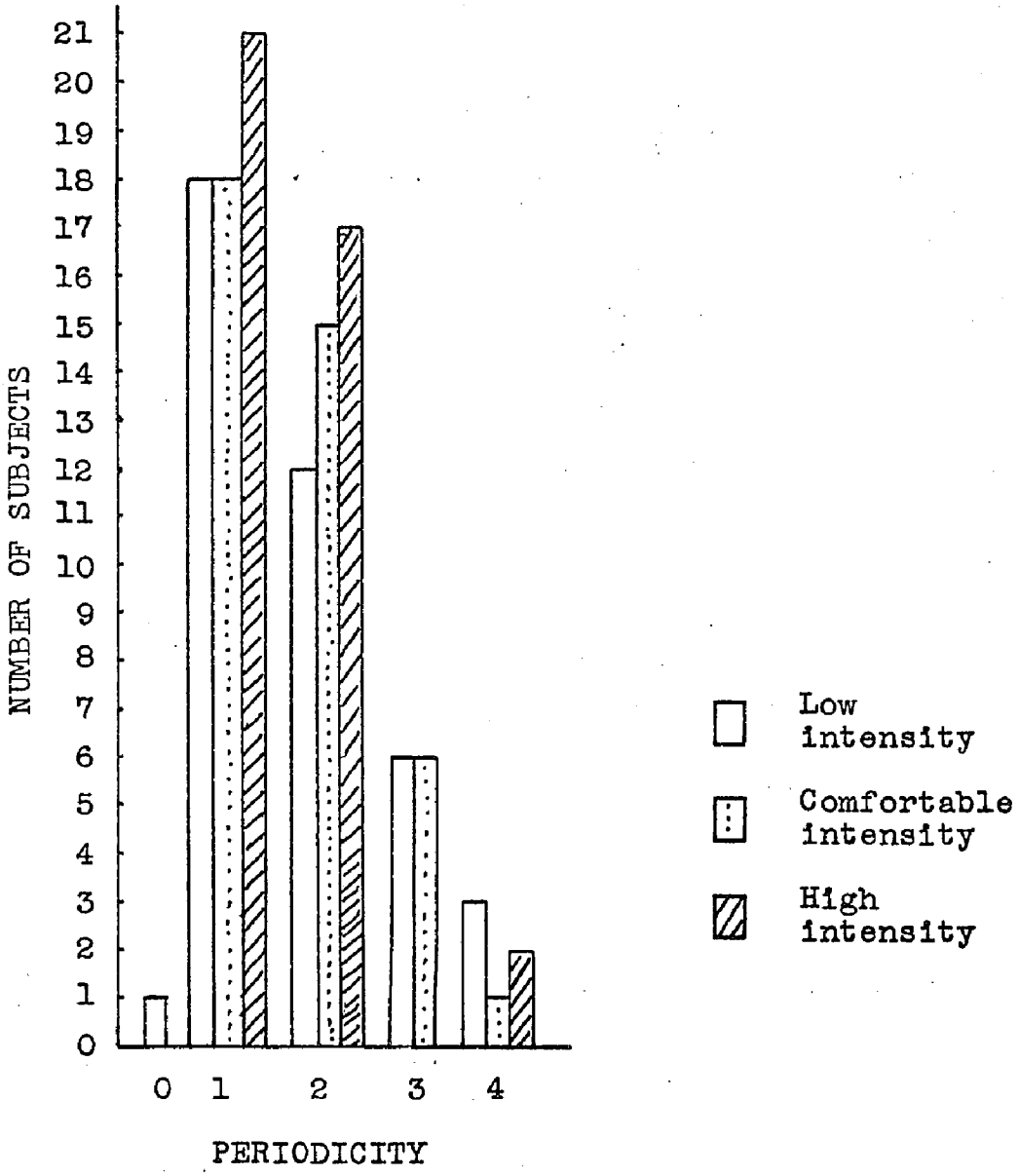


Figure 28. Periodicity values when forty young adult subjects produced vocal fold diadochokinesis in a comfortably pitched voice across three levels of vocal intensity.

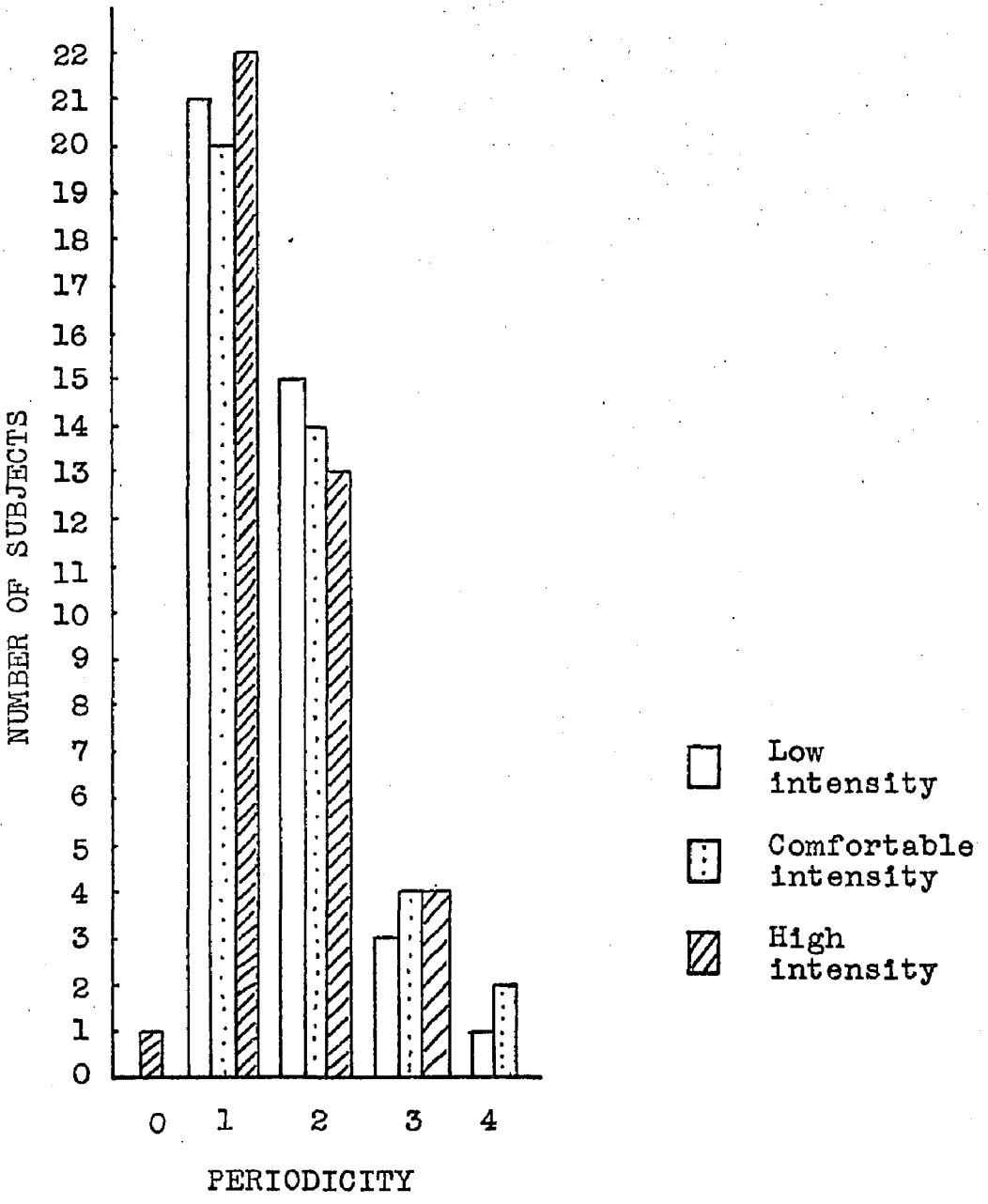


Figure 29. Periodicity values when forty young adult subjects produced vocal fold diadochokinesis in a high pitched voice across three levels of vocal intensity.

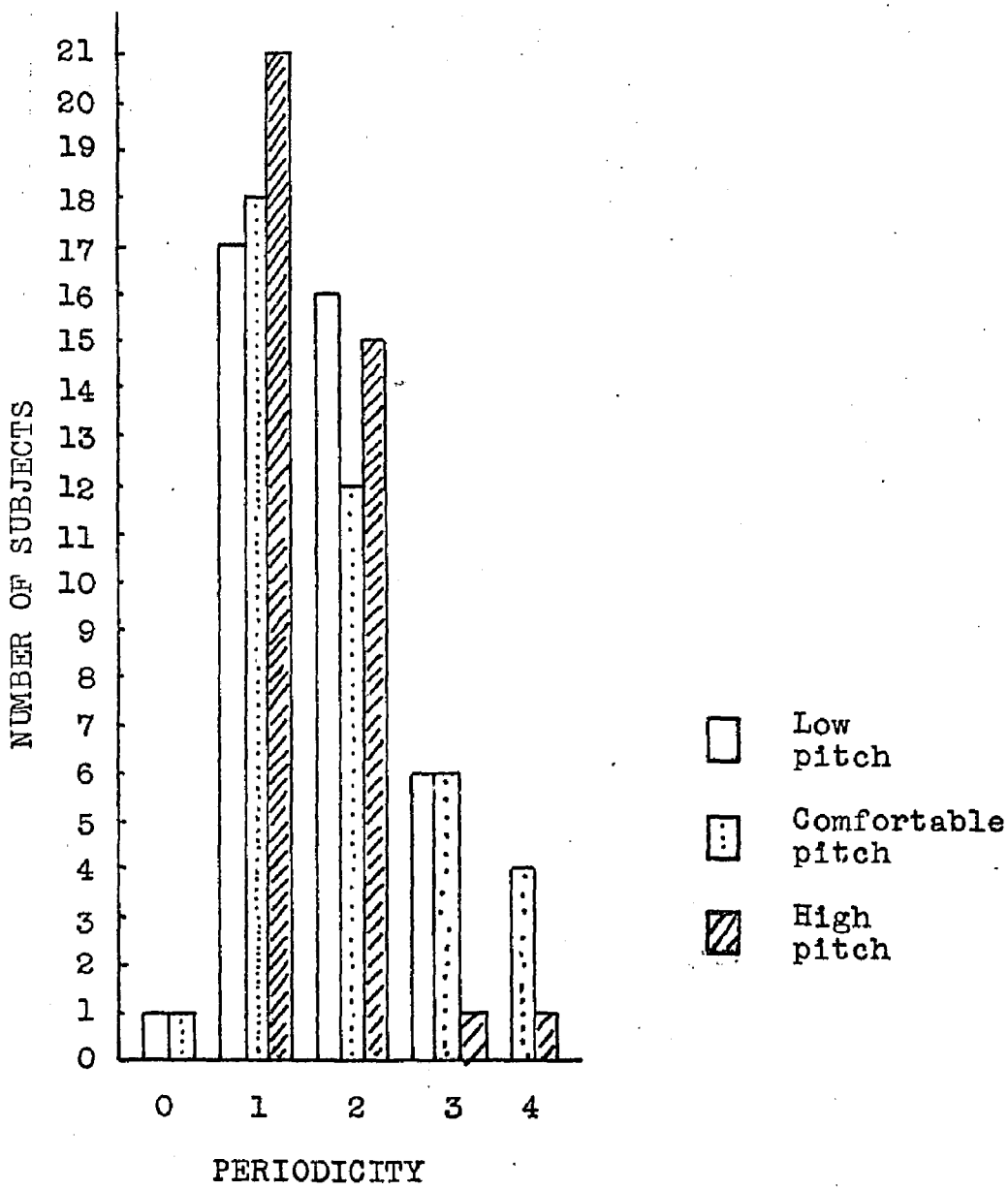


Figure 30. Periodicity values when forty young adult subjects produced vocal fold diadochokinesis at a low intensity level across three levels of vocal pitch.

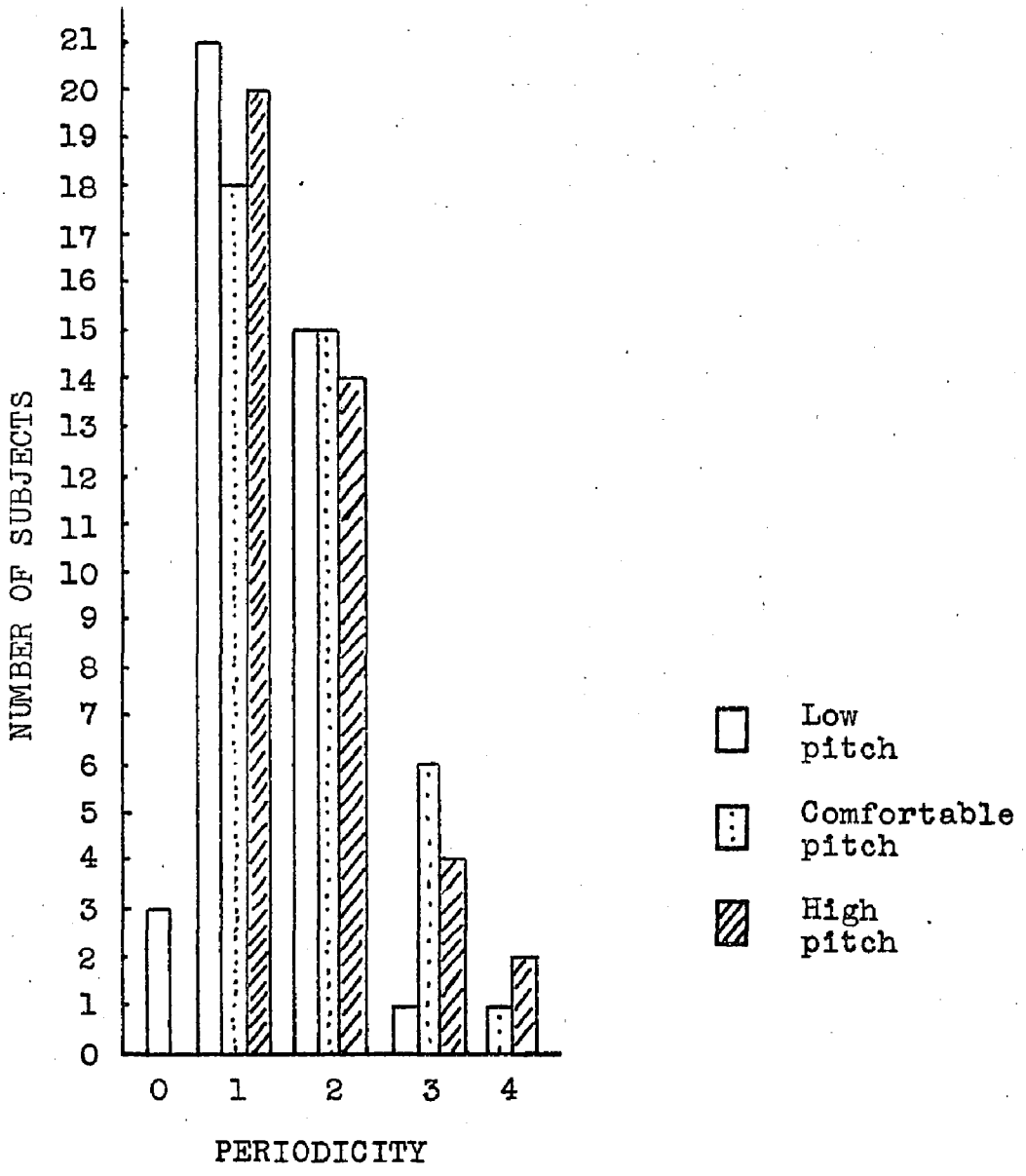


Figure 31. Periodicity values when forty young adult subjects produced vocal fold diadochokinesis at a comfortable intensity level across three levels of vocal pitch.

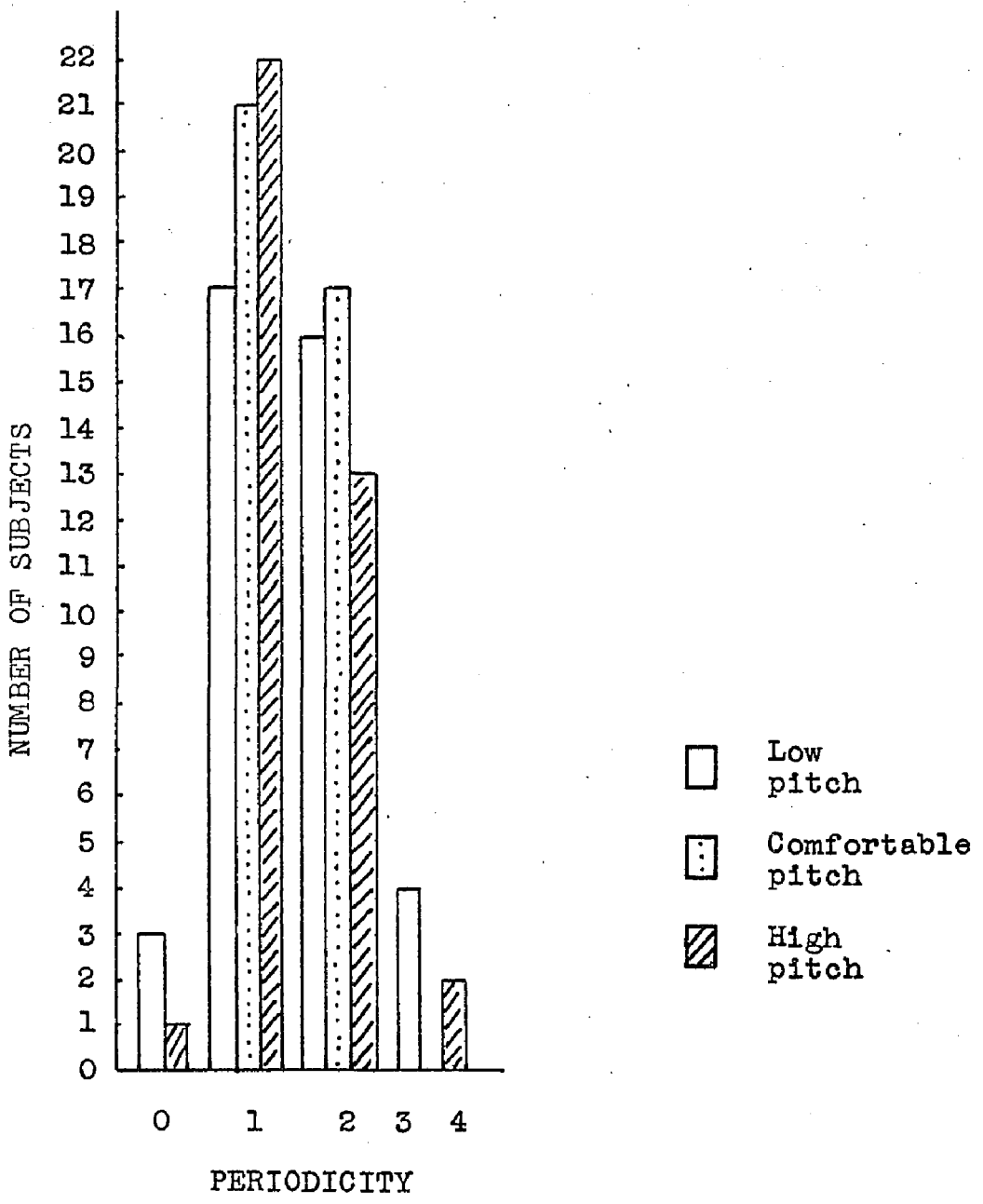


Figure 32. Periodicity values when forty young adult subjects produced vocal fold diadochokinesis at a high intensity level across three levels of vocal pitch.

TABLE XXXI

PERIODICITY OF VOCAL FOLD DIADOCHOKINESIS AS PERFORMED BY FORTY YOUNG ADULT SUBJECTS AT (1) LOW PITCH-LOW INTENSITY, (2) LOW PITCH-COMFORTABLE INTENSITY, (3) LOW PITCH-HIGH INTENSITY, (4) COMFORTABLE PITCH-LOW INTENSITY, (5) COMFORTABLE PITCH-COMFORTABLE INTENSITY, (6) COMFORTABLE PITCH-HIGH INTENSITY, (7) HIGH PITCH-LOW INTENSITY, (8) HIGH PITCH-COMFORTABLE INTENSITY, AND (9) HIGH PITCH-HIGH INTENSITY LEVELS TO EVALUATE THE EFFECTS OF VARIATIONS IN PITCH AND INTENSITY

SUBJECTS	TREATMENTS								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	2	2	1	1	2	1	2	2	2
2	1	1	2	1	3	1	2	2	1
3	2	2	2	1	1	1	2	1	1
4	2	1	1	1	2	1	1	1	2
5	3	1	1	1	1	1	1	1	3
6	1	1	1	4	2	1	2	2	3
7	1	1	0	3	3	1	4	1	1
8	1	2	1	1	2	2	1	2	1
9	2	2	3	2	1	2	2	4	3
10	2	2	2	1	2	1	1	1	1
11	3	1	1	2	1	1	2	2	2
12	3	3	3	3	2	1	1	3	2
13	1	1	0	2	1	2	2	2	1
14	3	1	2	2	3	2	1	2	1
15	3	2	2	3	1	1	2	3	2
16	2	2	1	2	2	2	1	1	1
17	1	2	1	2	2	2	2	1	2
18	1	1	2	3	2	2	1	2	1
19	1	1	1	1	1	2	1	1	1
20	2	2	2	2	2	2	2	2	2

TABLE XXXI (continued)

SUBJECTS	TREATMENTS								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
21	1	1	2	2	2	2	2	3	3
22	1	1	2	1	1	1	2	1	1
23	1	1	1	3	3	2	3	1	2
24	1	1	2	1	2	1	2	1	1
25	2	2	1	3	1	1	3	1	2
26	2	1	1	1	1	1	1	1	1
27	1	1	0	4	3	4	1	2	2
28	1	1	1	1	1	2	1	1	1
29	2	1	2	4	2	2	1	2	1
30	2	1	1	0	1	1	1	1	1
31	2	1	2	1	3	2	2	4	2
32	2	1	2	1	1	4	2	1	1
33	2	2	2	1	1	1	1	1	1
34	2	2	2	2	2	1	1	2	1
35	0	0	1	1	1	2	1	2	1
36	2	1	3	2	2	1	1	3	2
37	1	2	1	2	1	1	2	1	2
38	1	2	3	2	4	2	3	1	1
39	1	0	2	1	1	1	1	2	0
40	1	2	1	1	1	2	1	1	1
Mean	1.68	1.35	1.52	1.80	1.75	1.58	1.60	1.70	1.50
Standard Deviation	.76	.66	.78	.99	.81	.75	.74	.85	.72

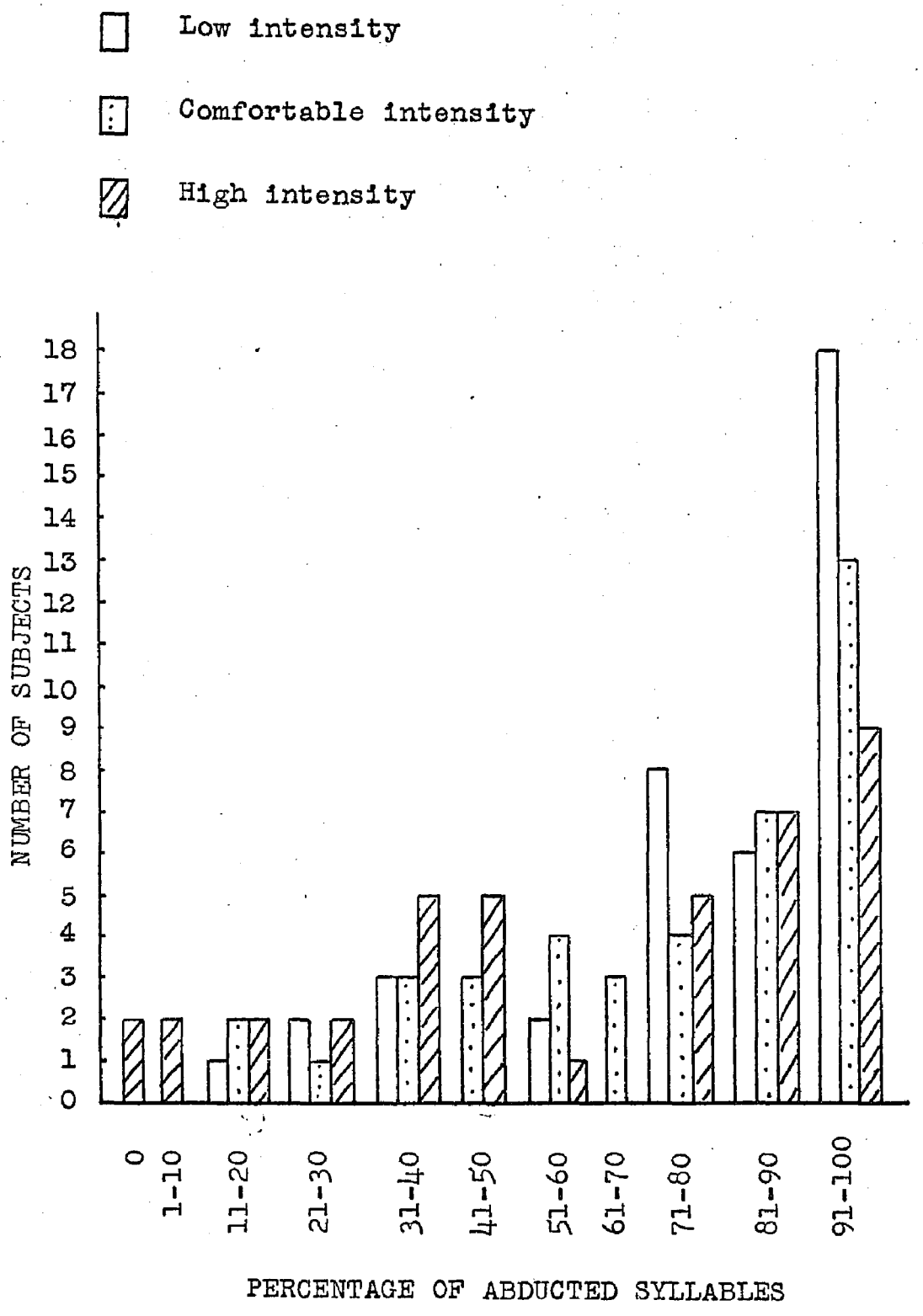


Figure 33. Percentage of abducted syllables when forty young adult subjects performed vocal fold diadochokinesis in a low pitched voice across three levels of vocal intensity.

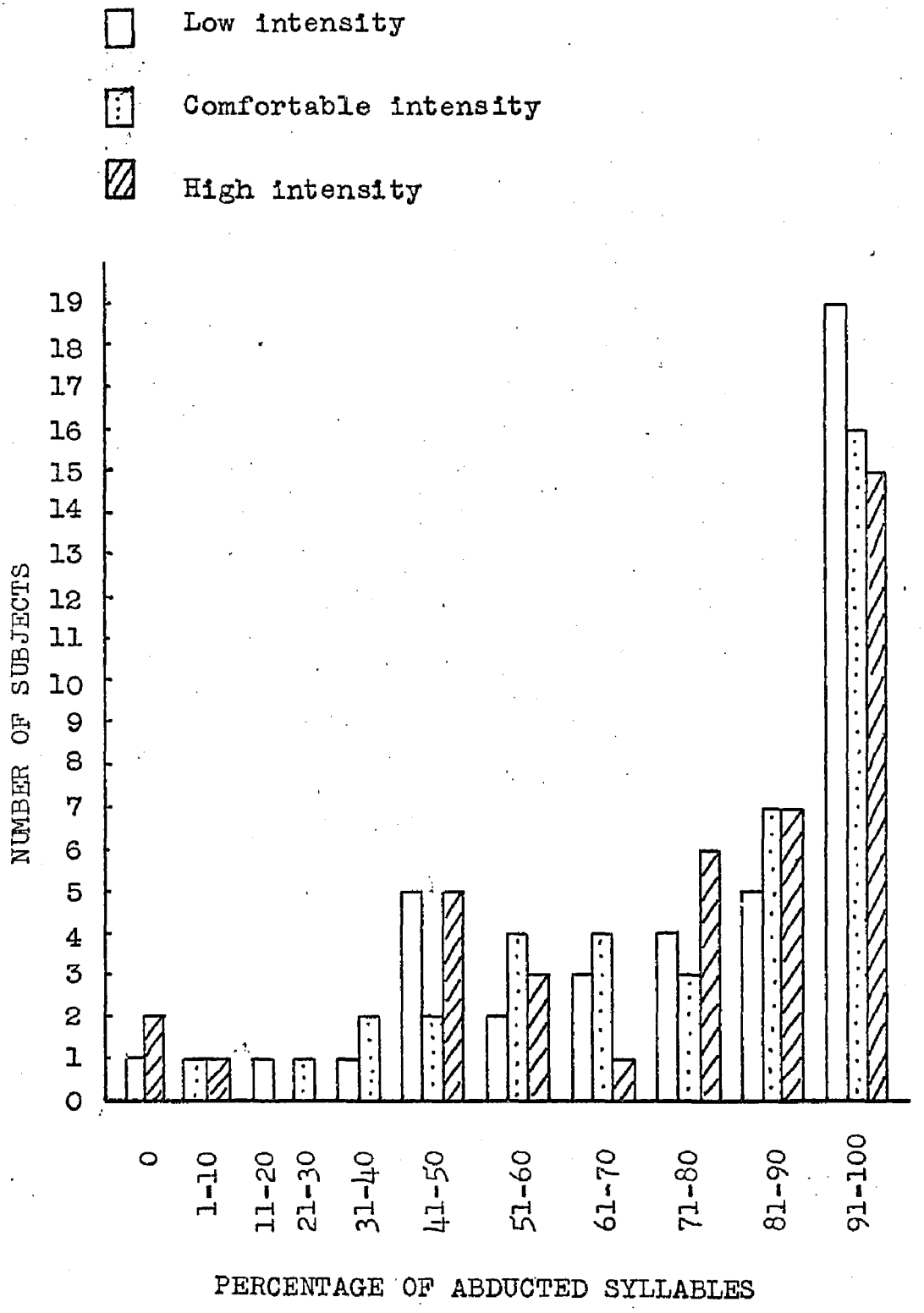


Figure 34. Percentage of abducted syllables when forty young adult subjects performed vocal fold diadochokinesis in a comfortably pitched voice across three levels of vocal intensity.

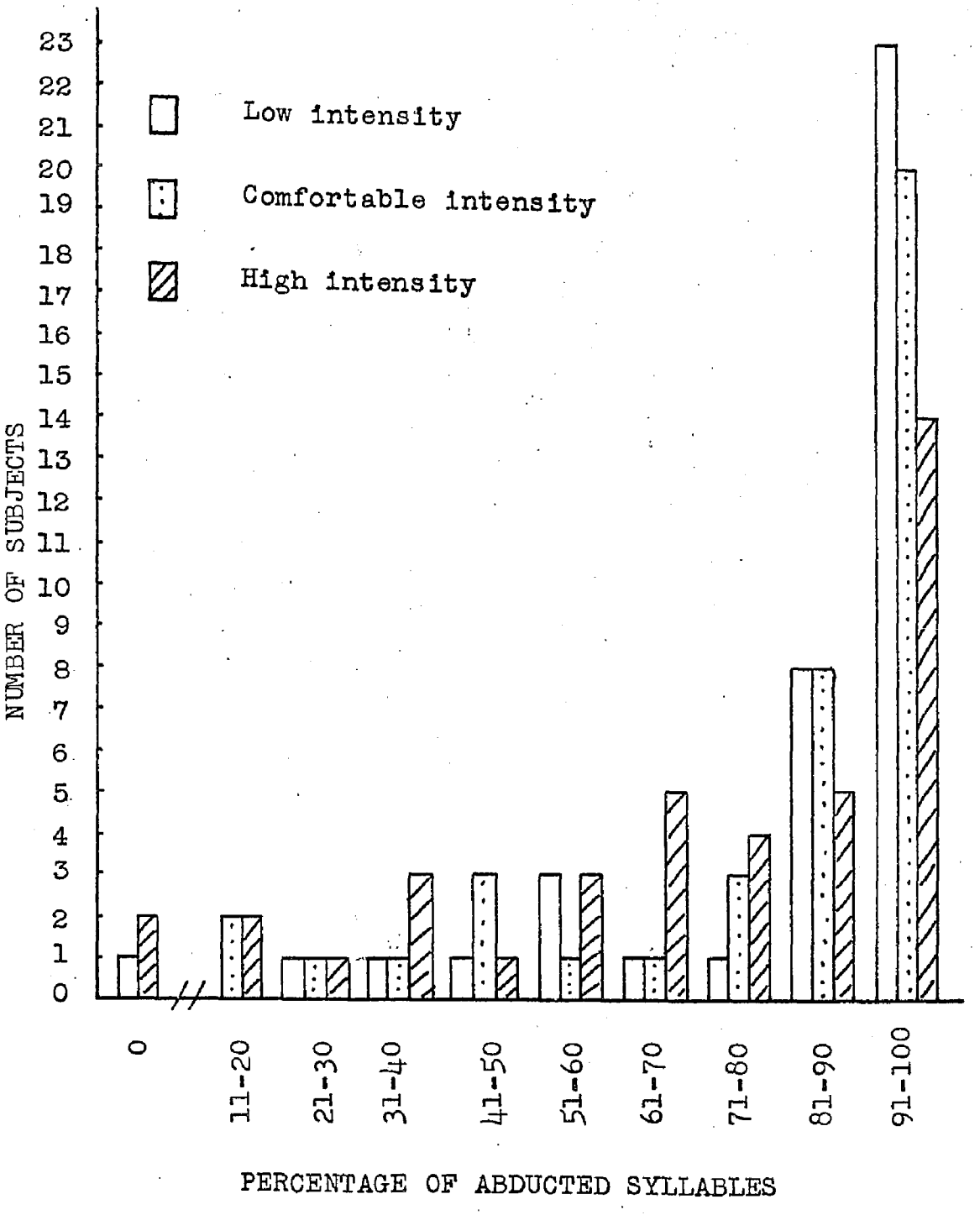


Figure 35. Percentage of abducted syllables when forty young adult subjects performed vocal fold diadochokinesis in a high pitched voice across three levels of vocal intensity.

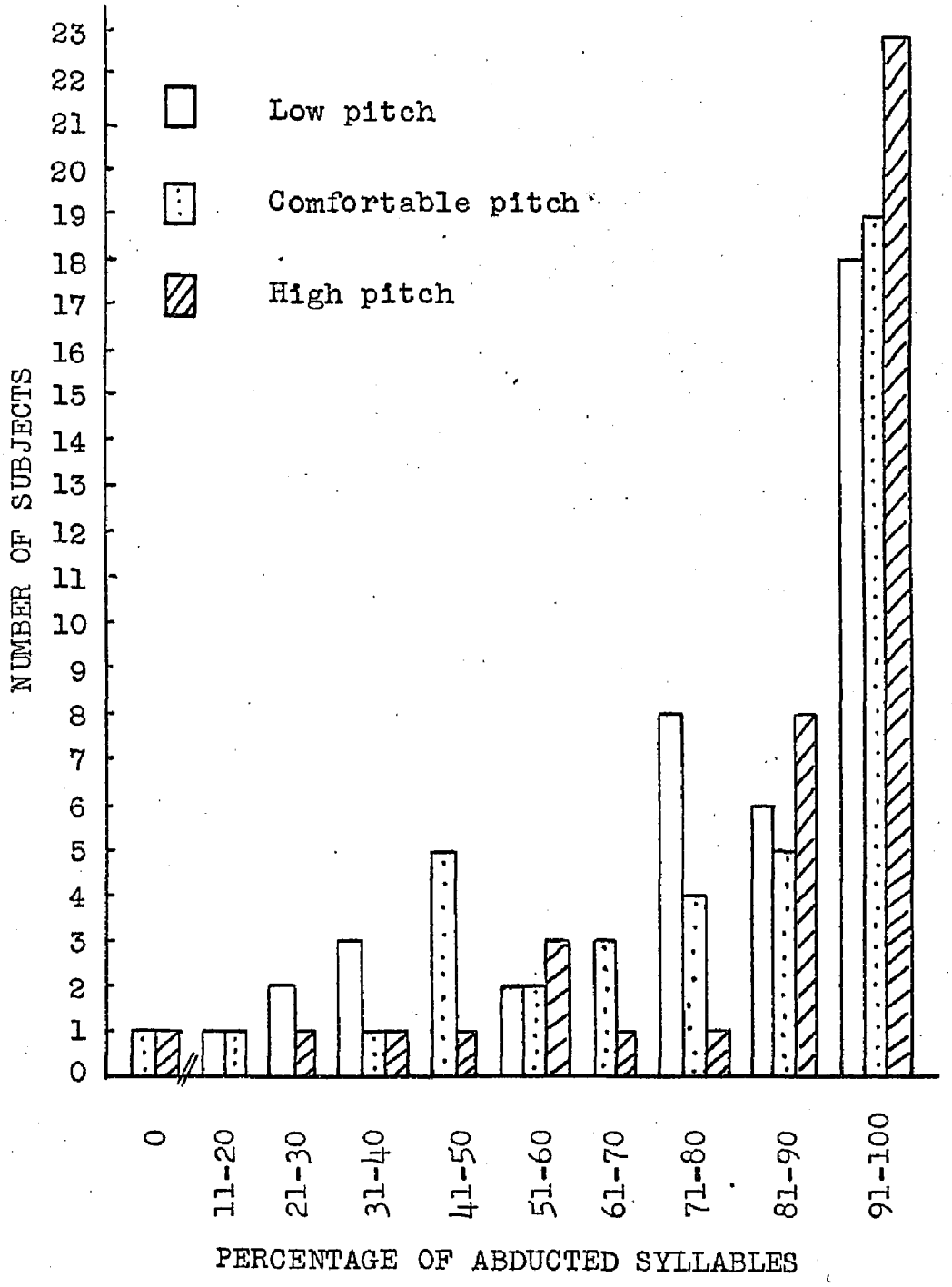


Figure 36. Percentage of abducted syllables when forty young adult subjects performed vocal fold diadochokinesis at a low intensity level across three levels of vocal pitch.

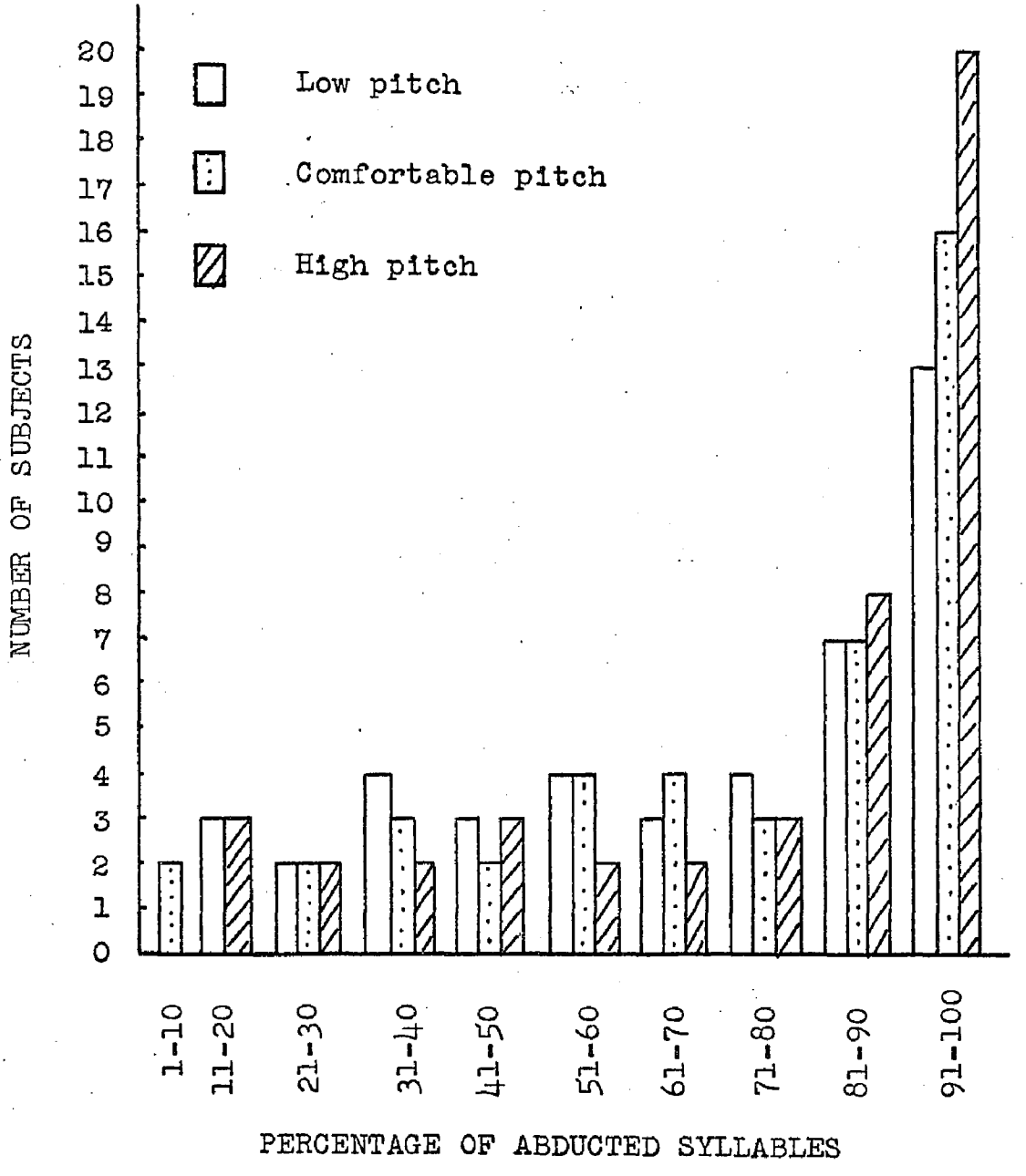


Figure 37. Percentage of abducted syllables when forty young adult subjects performed vocal fold diadochokinesis at a comfortable intensity level across three levels of vocal pitch.

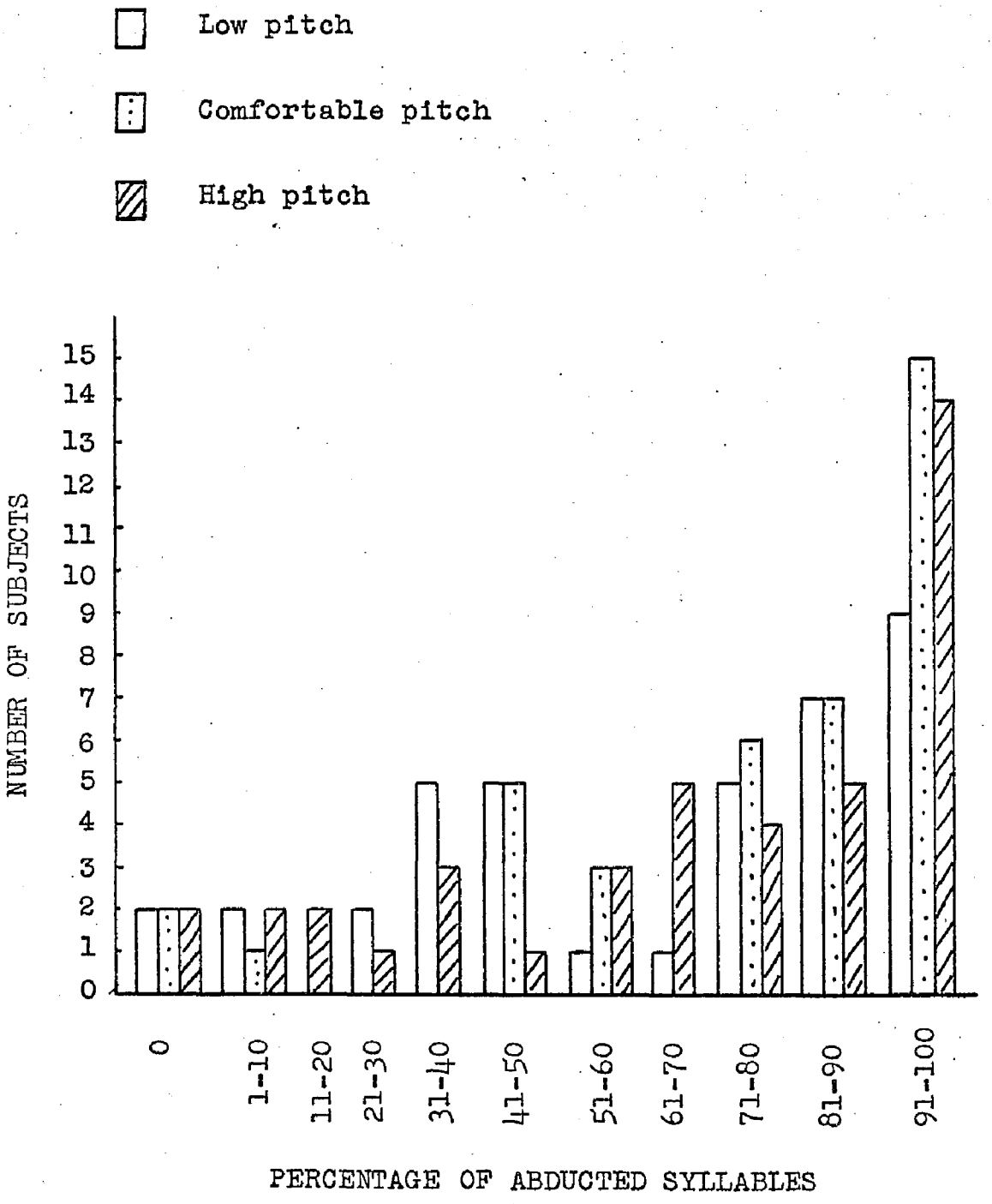


Figure 38. Percentage of abducted syllables when forty young adult subjects performed vocal fold diadochokinesis at a high intensity level across three levels of vocal pitch.

TABLE XXXII

PERCENTAGE OF ABDUCTED SYLLABLES WHEN VOCAL FOLD DIADOCHOKINESIS WAS PERFORMED BY FORTY YOUNG ADULT SUBJECTS AT (1) LOW PITCH-LOW INTENSITY, (2) LOW PITCH-COMFORTABLE INTENSITY, (3) LOW PITCH-HIGH INTENSITY, (4) COMFORTABLE PITCH-LOW INTENSITY, (5) COMFORTABLE PITCH-COMFORTABLE INTENSITY, (6) COMFORTABLE PITCH-HIGH INTENSITY, (7) HIGH PITCH-LOW INTENSITY, (8) HIGH PITCH-COMFORTABLE INTENSITY, AND (9) HIGH PITCH-HIGH INTENSITY LEVELS TO EVALUATE THE EFFECTS OF VARIATIONS IN PITCH AND INTENSITY

SUBJECTS	TREATMENTS								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	100	80	20	83.33	90	100	81.82	81.82	58.33
2	100	91.67	80	100	100	100	100	100	100
3	90.91	100	75	100	100	80	100	100	100
4	91.67	100	91.67	100	91.67	75	100	100	100
5	40	100	42.86	45.45	61.54	46.15	100	78.57	69.23
6	83.33	57.14	20	40	25	71.43	100	100	66.67
7	93.33	100	100	100	40	7.69	100	41.67	16.67
8	80	100	100	100	83.33	100	54.55	72.73	80
9	100	15.38	73.33	84.62	92.31	83.33	53.85	44.44	50
10	83.33	100	60	100	63.64	81.82	100	100	90.91
11	81.82	58.33	81.82	100	100	72.73	100	90.91	80
12	72.73	63.64	45.45	100	53.85	90.91	100	72.73	80
13	21.43	75	100	100	78.57	100	100	81.82	100
14	37.50	33.33	44.44	100	87.50	81.82	90	18.18	88.89
15	100	83.33	83.33	72.73	54.55	91.67	85.71	55.56	0
16	90	88.89	50	100	91.67	90	100	100	33.33
17	100	71.43	87.50	90	87.50	100	77.78	90.91	60
18	100	84.62	40	100	100	53.85	100	88.89	100
19	72.73	83.33	0	100	58.33	50	91.67	100	81.82

TABLE XXXII (continued)

SUBJECTS	TREATMENTS								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
20	100	18.18	90	64.29	58.33	64.29	81.82	90.91	91.67
21	100	75	100	100	100	84.62	81.82	100	66.67
22	100	100	100	100	92.31	100	90.91	88.89	100
23	100	100	85.71	100	66.67	100	100	100	100
24	87.50	62.50	100	88.89	80	100	87.50	88.89	88.89
25	100	66.67	100	88.89	100	100	100	100	100
26	80	100	88.89	72.73	72.73	60	100	100	88.89
27	100	100	75	72.73	90	45.45	100	100	90.91
28	90.91	100	25	63.64	81.82	75	100	100	100
29	75	50	71.43	66.67	88.89	90	87.50	81.82	87.50
30	80	90	50	100	91.67	100	100	100	72.73
31	90	85.71	100	45.45	33.33	100	100	62.50	100
32	36.36	83.33	9.09	53.85	0	41.67	70	20	64.29
33	72.73	50	0	50	45.45	0	100	81.82	58.33
34	54.55	55.56	22.22	41.67	100	91.67	88.89	33.33	0
35	100	100	90	75	100	45.45	50	90.91	36.36
36	55.56	30.77	8.33	54.55	76.92	0	0	100	33.33
37	16.67	50	33.33	44.44	91.67	16.67	33.33	25	20
38	77.78	38.46	33.33	9.09	83.33	75	60	42.86	28.57
39	100	53.33	40	92.31	92.31	92.86	90.91	100	100
40	22.22	33.33	33.33	100	45.45	54.55	27.27	90	70
Mean	79.45	73.22	61.28	80.81	76.66	72.84	84.63	80.38	71.35
Standard Deviation	24.78	25.69	32.88	24.02	24.49	29.21	23.72	25.30	29.74

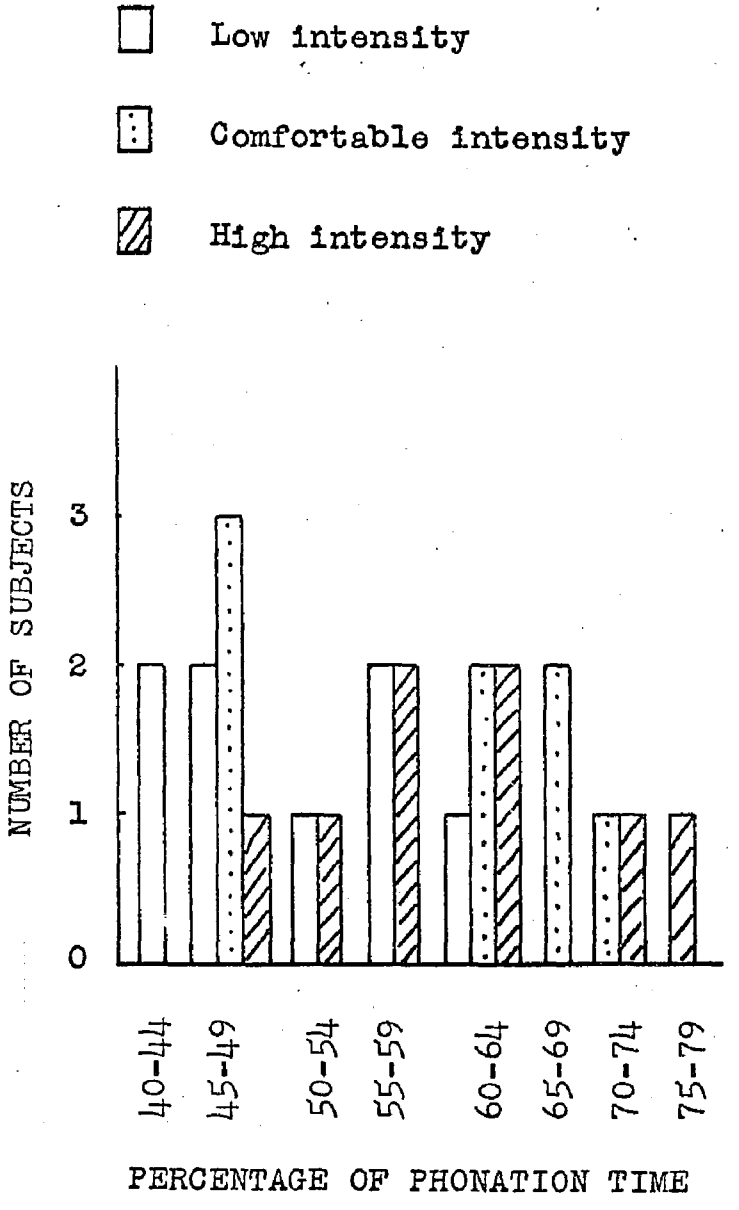


Figure 39. Percentage of phonation time when three groups each including eight young adult subjects performed vocal fold diadochokinesis in a low pitched voice across three levels of vocal intensity.

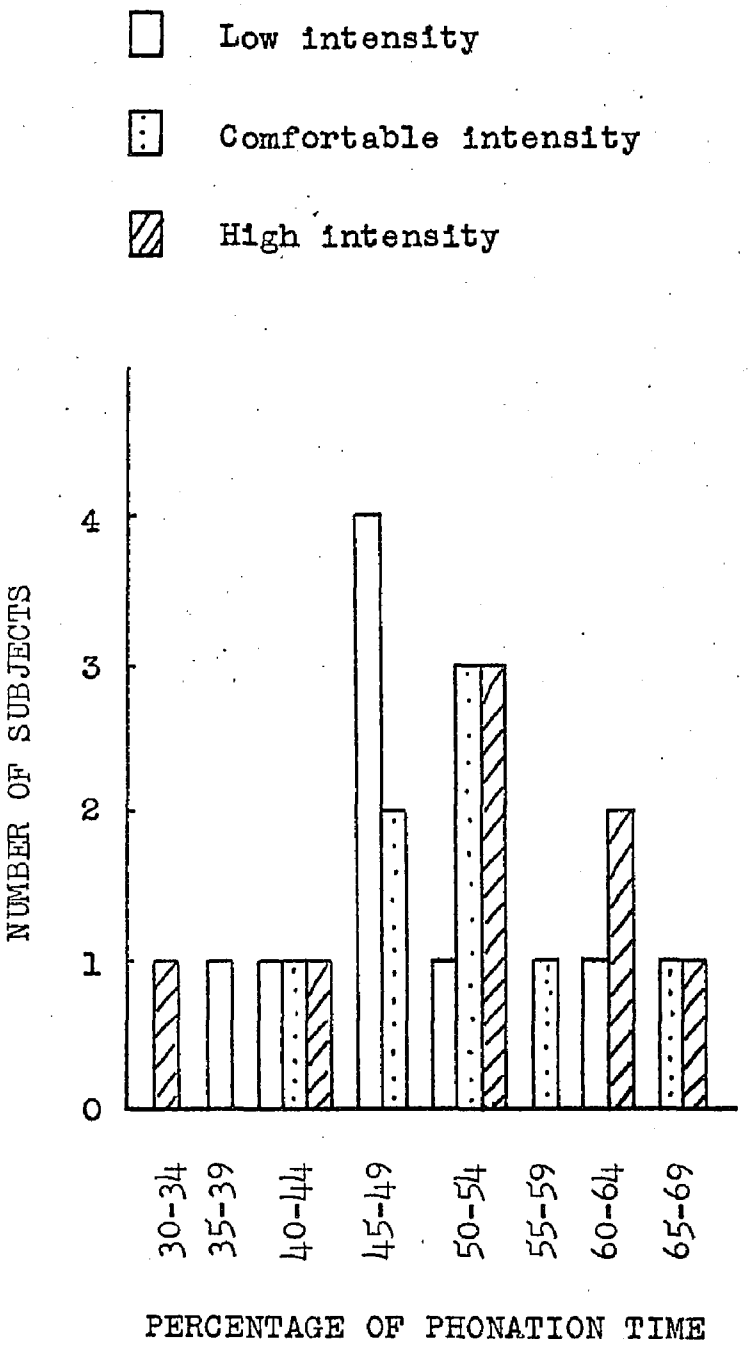


Figure 40. Percentage of phonation time when three groups each including eight young adult subjects performed vocal fold diadochokinesis in a comfortably pitched voice across three levels of vocal intensity.

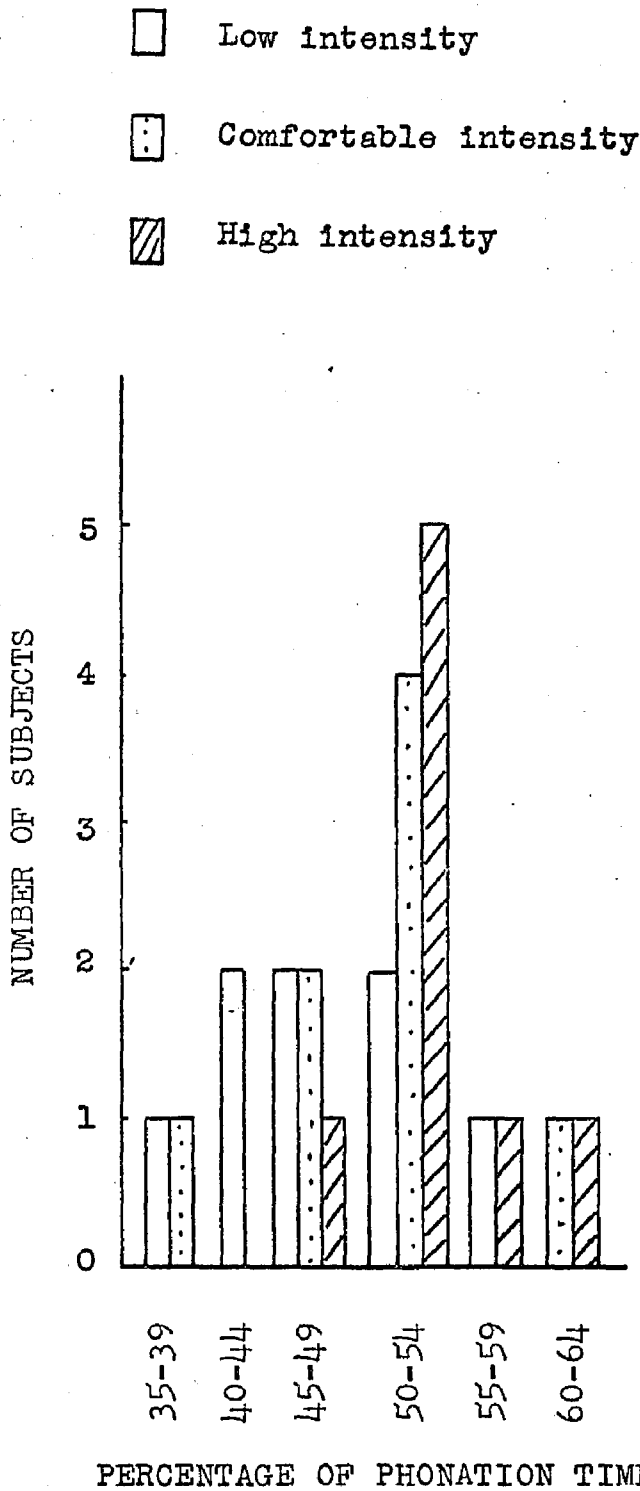


Figure 41. Percentage of phonation time when three groups each including eight young adult subjects performed vocal fold diadochokinesis in a high pitched voice across three levels of vocal intensity.

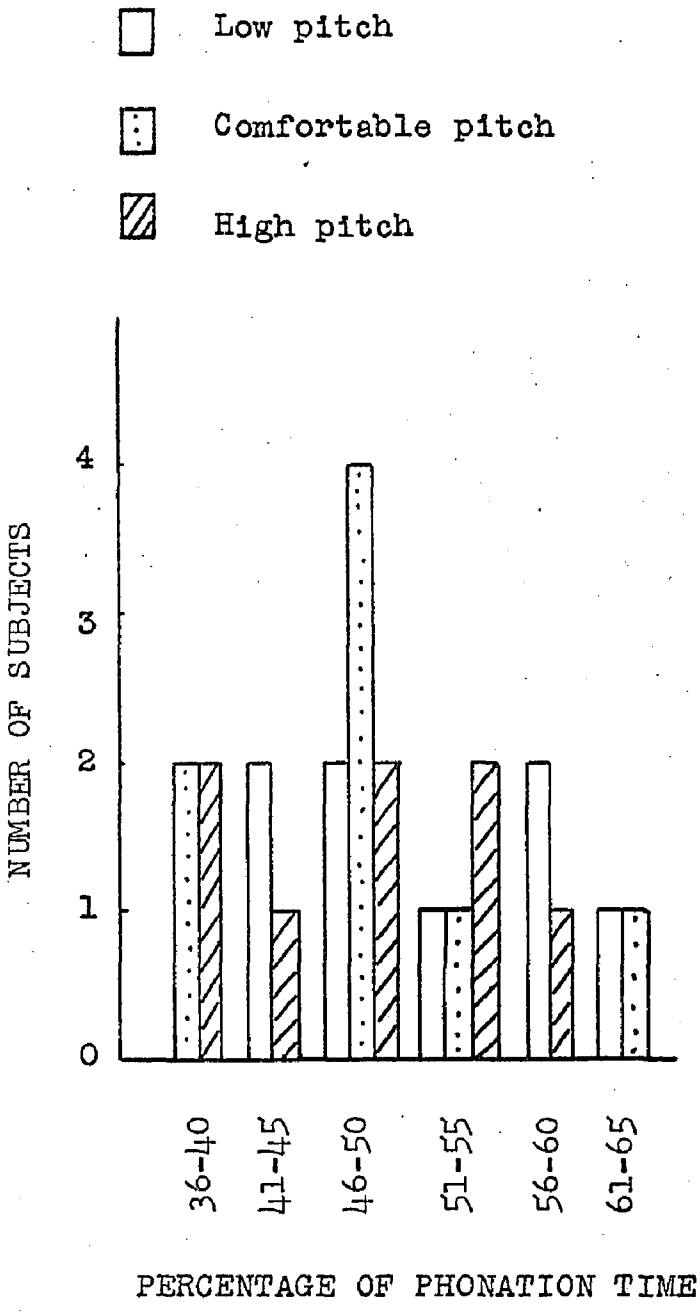


Figure 42. Percentage of phonation time when three groups each including eight young adult subjects performed vocal fold diadochokinesis at a low intensity level across three levels of vocal pitch.

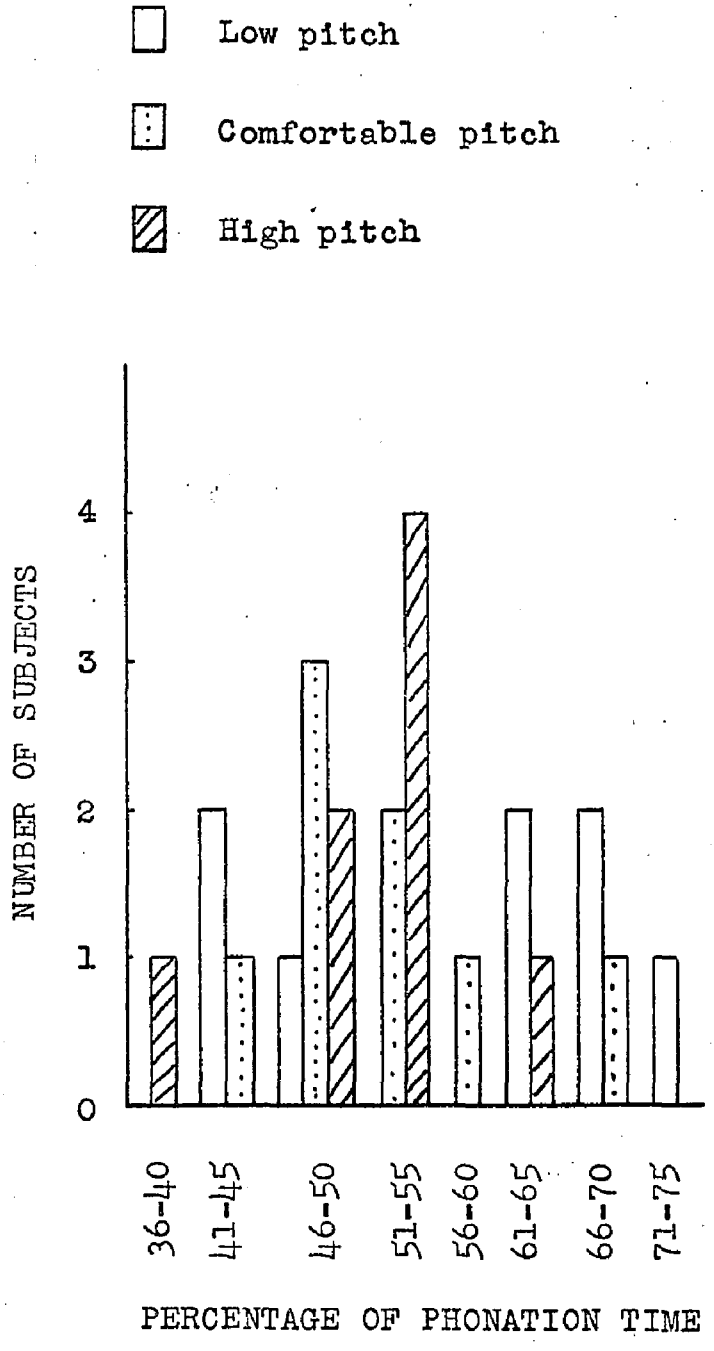


Figure 43. Percentage of phonation time when three groups each including eight young adult subjects performed vocal fold diadochokinesis at a comfortable intensity level across three levels of vocal pitch.

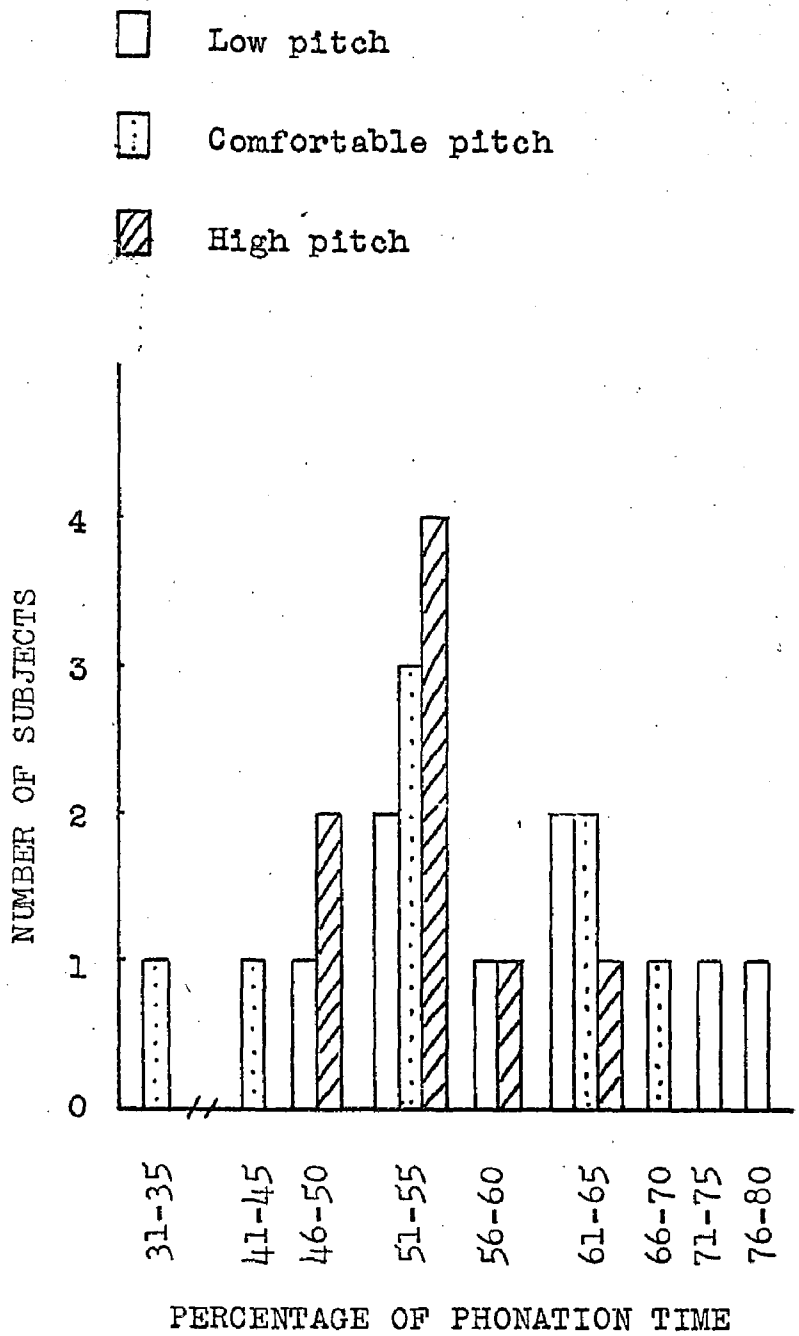


Figure 44. Percentage of phonation time when three groups each including eight young adult subjects performed vocal fold diadochokinesis at a high intensity level across three levels of vocal pitch.

TABLE XXXIII

PERCENTAGE OF PHONATION TIME WHEN NINE GROUPS EACH INCLUDING EIGHT YOUNG ADULT SUBJECTS PERFORMED VOCAL FOLD DIADOCHOKINESIS AT (1) LOW PITCH-LOW INTENSITY, (2) LOW PITCH-COMFORTABLE INTENSITY, (3) LOW PITCH-HIGH INTENSITY, (4) COMFORTABLE PITCH-LOW INTENSITY, (5) COMFORTABLE PITCH-COMFORTABLE INTENSITY, (6) COMFORTABLE PITCH-HIGH INTENSITY, (7) HIGH PITCH-LOW INTENSITY, (8) HIGH PITCH-COMFORTABLE INTENSITY, AND (9) HIGH PITCH-HIGH INTENSITY LEVELS TO EVALUATE THE EFFECTS OF VARIATIONS IN PITCH AND INTENSITY

SUBJECTS	TREATMENTS								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	47.95	66.62	61.34	46.96	53.08	62.45	54.02	52.29	51.24
2	42.26	61.99	52.08	63.72	46.10	33.98	38.36	53.03	62.97
3	62.93	69.20	76.25	46.58	59.43	40.62	44.33	64.60	47.05
4	53.65	45.04	45.68	52.96	40.57	52.26	56.88	46.68	50.15
5	56.56	47.57	73.11	38.53	68.85	62.87	46.18	52.31	51.36
6	49.66	72.51	55.24	49.48	46.04	51.24	52.76	46.14	57.04
7	41.85	45.44	62.29	40.01	54.08	67.30	46.31	53.09	54.01
8	58.91	62.77	59.55	46.62	50.36	53.46	40.25	37.84	53.58
Mean	51.72	58.89	60.69	48.11	52.31	53.02	47.39	50.75	53.42
Standard Deviation	7.65	11.19	10.21	7.86	8.84	11.40	6.63	7.67	4.85

TABLE XXXIV

RATES (PER SECOND), PERIODICITY, PERCENTAGE OF ABDUCTED SYLLABLES, AND PERCENTAGE OF PHONATION TIME WHEN VOCAL FOLD DIADOCHOKINESIS WAS PRODUCED AT A COMFORTABLE PITCH AND INTENSITY LEVEL BY YOUNG ADULT WOMEN

SUBJECTS	RATES	PERIODICITY	ABDUCTED SYLLABLES	PHONATION TIME[a]
1	5.44	2	90	
2	5	3	100	53.08
3	4.44	1	100	46.10
4	6.11	2	91.67	
5	6.11	1	61.54	
6	5.89	2	25	
7	5.22	3	40	
8	4.44	2	83.33	
9	6.22	1	92.31	
10	5.44	2	63.64	
11	4.89	1	100	59.43
12	5.89	2	53.85	
13	6.22	1	78.57	
14	4.78	3	87.50	
15	5.67	1	54.55	
16	5	2	91.67	
17	4	2	87.50	
18	5.89	2	100	40.57
19	5.78	1	58.33	
20	6	2	58.33	
21	5.22	2	100	68.85
22	5.56	1	92.31	
23	4.56	3	66.67	
24	5	2	80	
25	5.22	1	100	46.04
26	5.56	1	72.73	
27	5	3	90	
28	5.44	1	81.82	
29	5.44	2	88.89	
30	5.67	1	91.67	
31	5.33	3	33.33	

TABLE XXXIV (continued)

SUBJECTS	RATES	PERIODICITY	ABDUCTED SYLLABLES	PHONATION TIME
32	5.44	1	0	
33	5.44	1	45.45	
34	5.33	2	100	54.08
35	5.56	1	100	50.36
36	6.56	2	76.92	
37	5.56	1	91.67	
38	6.22	4	83.33	
39	6.33	1	92.31	
40	5.33	1	45.45	
Mean	5.46	1.75	76.66	52.31
Standard Deviation	.57	.81	24.49	8.84

[a]Data obtained from spectrograms with 100 per cent abducted syllables.

TABLE XXXV

RATES (PER SECOND), PERIODICITY, PERCENTAGE OF ABDUCTED SYLLABLES, AND PERCENTAGE OF PHONATION TIME WHEN VOCAL FOLD DIADOCHOKINESIS WAS PRODUCED AT A COMFORTABLE PITCH AND INTENSITY LEVEL BY MATURE WOMEN

SUBJECTS	RATES	PERIODICITY	ABDUCTED SYLLABLES	PHONATION TIME[a]
1	6.22	3	100	58.11
2	6.22	1	100	
3	4.89	2	66.67	
4	4.44	3	100	
5	5	3	63.64	
6	5.56	2	100	
7	5.44	1	100	42.99
8	4.33	2	88.89	
9	6.11	2	92.31	
10	5.78	1	83.33	
11	5.67	1	75	
12	6.44	3	73.33	
13	6.56	1	85.71	
14	5.78	1	100	
15	5.11	2	40	
16	6.33	1	100	57.60
17	6.22	3	100	
18	6.11	2	100	57.24
19	6.78	3	60	
20	6	2	100	
21	5.67	1	66.67	
22	5.11	2	100	59.49
23	6.33	1	100	54.76
24	6.44	1	100	
25	4.67	3	88.89	
26	6	2	66.67	
27	6.44	4	73.33	
28	5.44	2	80	
29	5.22	2	81.82	
30	6.11	1	69.23	
31	5.33	2	90.91	

TABLE XXXV (continued)

SUBJECTS	RATES	PERIODICITY	ABDUCTED SYLLABLES	PHONATION TIME
32	5.33	1	100	59.24
33	6	2	100	
34	4.44	2	88.89	
35	6.67	1	100	57.54
36	5.89	2	100	
37	5.33	2	0	
38	5.33	2	100	
39	6.33	1	100	
40	5.67	2	100	
Mean	5.72	1.88	85.88	55.87
Standard Deviation	.64	.79	20.63	5.40

[a]Data obtained from eight spectrograms chosen at random.

TABLE XXXVI

RATES (PER SECOND), PERIODICITY, PERCENTAGE OF ABDUCTED SYLLABLES, AND PERCENTAGE OF PHONATION TIME WHEN VOCAL FOLD DIADOCHOKINESIS WAS PRODUCED AT A COMFORTABLE PITCH AND INTENSITY LEVEL BY WOMEN IN THE LATE SENESCENT PERIOD OF LIFE

SUBJECTS	RATES	PERIODICITY	ABDUCTED SYLLABLES	PHONATION TIME[a]
1	5.33	2	66.67	
2	6	0	69.23	
3	6.11	1	100	53.94
4	5.78	2	100	45.64
5	6.89	2	86.67	
6	5.56	3	100	45.21
7	6.22	1	83.33	
8	5.11	2	100	
9	5.67	1	100	
10	5.33	2	38.46	
11	5.67	1	100	
12	4.56	2	20	
13	5.56	1	100	
14	6.56	1	93.33	
15	6.22	3	90.91	
16	6	1	83.33	
17	5.56	1	100	
18	5.33	1	100	
19	4.56	1	88.89	
20	5.33	2	100	
21	5.78	2	91.67	
22	6	2	78.57	
23	5.89	1	91.67	
24	6.89	1	92.86	
25	5.78	2	41.67	
26	5.89	2	92.31	
27	5.44	1	90.91	
28	5.78	3	75	
29	6.56	1	100	
30	5.89	1	100	53.28

TABLE XXXVI (continued)

SUBJECTS	RATES	PERIODICITY	ABDUCTED SYLLABLES	PHONATION TIME
31	4.56	1	90	
32	6.11	2	100	
33	3.89	2	100	46.55
34	3.33	2	100	
35	5.11	3	100	67.50
36	4.67	1	100	57.76
37	5.44	1	100	51.40
38	5.89	2	81.82	
39	5.22	4	100	
40	4.33	3	22.22	
Mean	5.54	1.68	86.74	52.66
Standard Deviation	.75	.83	21.18	7.48

[a]Data obtained from eight spectrograms chosen at random.

APPENDIX B

TABLE XXXVII

SUMMARY OF THE MEANS AND STANDARD DEVIATIONS OF PITCH (CYCLES PER SECOND) AND INTENSITY (db) WHEN FORTY YOUNG ADULT SUBJECTS PERFORMED THE TASKS DESIGNED TO MEASURE THE EFFECT OF DISRUPTING AUDITORY FEEDBACK ON VOCAL FOLD DIADOCHOKINESIS

CONDITION	MEAN PITCH	PITCH STANDARD DEVIATION	MEAN INTENSITY	INTENSITY STANDARD DEVIATION
Comfortable pitch and intensity	242.35	38.50	72.10	3.91
Comfortable pitch, controlled intensity, and auditory masking	241.63	41.18	74.46	3.47
Comfortable pitch, controlled intensity	239.46	24.41	72.29	2.92

TABLE XXXVIII

SUMMARY OF THE MEANS AND STANDARD DEVIATIONS OF THE PITCH (CYCLES PER SECOND) AND INTENSITY (db) WHEN THE FORTY YOUNG ADULT SUBJECTS PERFORMED VOCAL FOLD DIADOCHOKINESIS AT VARIED PITCH AND INTENSITY LEVELS

CONDITION	MEAN PITCH	PITCH STANDARD DEVIATION	MEAN INTENSITY	INTENSITY STANDARD DEVIATION
Low pitch-low intensity	185.83	23.64	62.89	3.57
Low pitch-comfortable intensity	194.61	22.73	71.73	3.66
Low pitch-high intensity	204.50	27.92	79.02	2.93
Low pitch-low, comfortable, and high intensity	195.05	23.97		
Comfortable pitch-low intensity	238.41	42.73	64.84	4.26
Comfortable pitch-comfortable intensity	242.35	38.50	72.10	3.91
Comfortable pitch-high intensity	254.12	35.98	79.62	3.42
Comfortable pitch-low, comfortable, and high intensity	242.48	31.23		
High pitch-low intensity	435.18	64.36	68.84	3.38

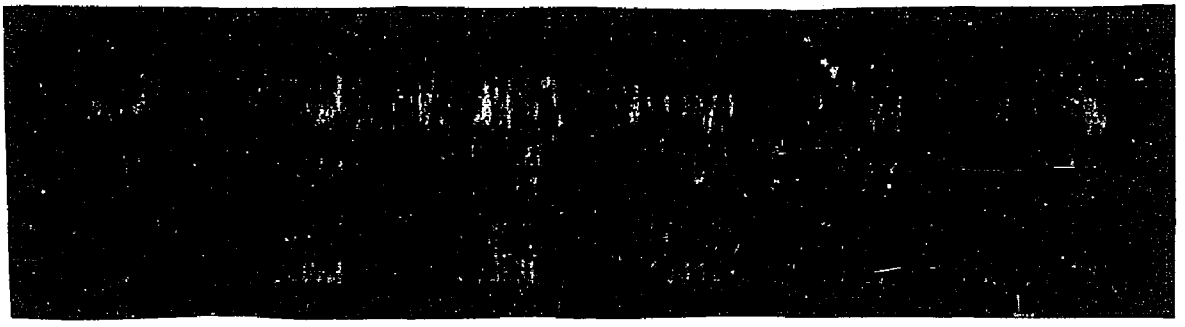
TABLE XXXVIII (continued)

CONDITION	MEAN PITCH	PITCH STANDARD DEVIATION	MEAN INTENSITY	INTENSITY STANDARD DEVIATION
High pitch-comfortable intensity	441.63	66.35	75.01	3.23
High pitch-high intensity	459.22	78.06	81.52	2.74
High pitch-low, comfortable, and high intensity	442.43	65.53		

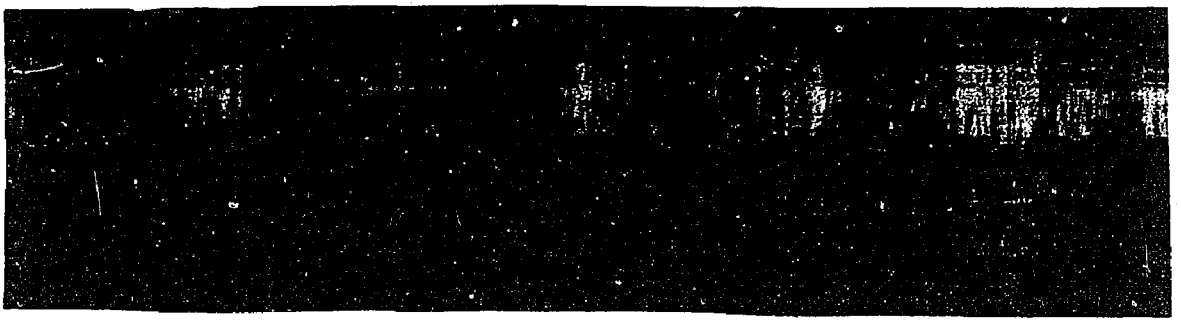
TABLE XXXIX

SUMMARY OF THE MEANS AND STANDARD DEVIATIONS OF PITCH (CYCLES PER SECOND) AND INTENSITY (db) WHEN THE FORTY YOUNG ADULT WOMEN, FORTY MATURE WOMEN, AND FORTY WOMEN IN THE LATE SENESCENT PERIOD OF LIFE PERFORMED THE TASKS TO EVALUATE THE EFFECTS OF AGING UPON VOCAL FOLD DIADOCHOKINESIS

GROUP	MEAN PITCH	PITCH STANDARD DEVIATION	MEAN INTENSITY	INTENSITY STANDARD DEVIATION
Young adult	242.35	38.50	72.10	3.91
Mature adult	225.01	42.66	71.00	6.02
Senescent adult	230.27	47.90	71.62	8.19



Syllables reflecting evidence of vocal fold diadochokinesis



Lack of friction fill corresponding to the [h] sound

Figure 45. Sound spectrograms illustrating percentage of abducted syllable measurements during rapid repetition of the syllable [hʌ].

AUTOBIOGRAPHY

Susan Jane Shanks was born July 6, 1930, in Toledo, Ohio. She attended grammar school there, and was graduated in June, 1948, from Thomas A. DeVilbiss High School. She was enrolled as a Freshman at Michigan State University during the 1948-49 academic year. A month before returning for the Sophomore year, she contracted Poliomyelitis.

Re-enrollment in college was postponed until September, 1954, when she entered the University of Toledo. She graduated, cum laude, from that institution in June, 1957, with a Bachelor of Education degree. During the summer she was enrolled as a graduate student in Speech and Hearing Therapy at Bowling Green State University.

From September, 1957, until June, 1958, she taught the seventh and eighth grades at St. Pius X School in Toledo, Ohio. In June, the writer re-enrolled at Bowling Green State University and was employed as a graduate assistant in the Speech Clinic during the 1958-59 academic year. In January, 1960, she received her Master of Arts degree from that University, and in October, she accepted a position as Speech Therapist at Samuel Gompers Memorial Rehabilitation Center in Phoenix, Arizona. She was employed at the Center until July, 1963, when she resigned to enroll as a doctoral candidate at Louisiana State University.

EXAMINATION AND THESIS REPORT

Candidate: Susan Jane Shanks

Major Field: Speech

Title of Thesis: An Investigation of the Nature of Vocal Fold Diadochokinesis and the Effect of Pitch and Intensity and of Aging Upon the Phonatory Task

Approved:

Gerald N. McCall
Major Professor and Chairman

Max Goodrich
Dean of the Graduate School

EXAMINING COMMITTEE:

Gary H. Gunn

Jack R. Buckley

C. A. Shamma

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Date of Examination:

July 20, 1966